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A. D.

Technical Report S-148

COMPARATIVE TESTS OF PROPELLANTS BY PEAK SIDE-ON OVERPRESSURE AND SIDE-ON IMPULSE(U)

by

T. H. Pratt

October 1967

U. S. ARMY MISSILE COMMAND
Redstone Arsenal, Alabama 35809

Contract DAAH01-67-C-0655

ROHM AND HAAS COMPANY
REDSTONE RESEARCH LABORATORIES
HUNTSVILLE, ALABAMA 35807

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FOREWORD

This work was performed under contract DAAH01-67-C-0655 for exploratory development of propellants for missiles and rockets. Six of the propellant samples were left over from a previous study[1] performed under contract DA-01-021 ORD-12341(Z) for comparative tests of Sprint candidate propellants. Both contracts are under the cognizance of the Army Propulsion Laboratory and Center, Research and Development Directorate, U. S. Army Missile Command.

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[1]Rohm and Haas Co., Huntsville, Alabama, COMPARATIVE TESTS OF SPRINT CANDIDATE PROPELLANTS(U), Ballistics Staff, 12 Feb. 1965, Report S-56, U. S. Army Missile Command, Redstone Arsenal, Alabama, Contract DA-01-021 ORD-12341(Z) (Confidential). AD-357 343.

ABSTRACT

Peak side-on overpressure and side-on impulse as a function of distance have been determined for 17 propellant formulations in a series of 31 shots. TNT equivalents based on overpressure and TNT equivalents based on impulse have been assigned the formulations examined. Blast overpressures and impulses were generated by 100-lbm propellant charges initiated with 25 lbm of high explosive and measured at distances from 40 to 80 feet from ground zero. It has been found that, depending on formulation, non-detonable propellants exhibit a TNT equivalent of 55 to 85 and that detonable propellants exhibit a TNT equivalent of 100 to 140. These TNT equivalents should be used in hazards classification only when stimuli are comparable.

CONTENTS

(U) Section I. INTRODUCTION

Unlike reactive-binder systems, inert-binder composite propellants are usually not capable of undergoing stable, high-velocity detonations. However, when subjected to shocks from high explosives, they do generate blast waves of appreciable force. The magnitude and shape of the blast waves generated by propellants greatly influence the degree and nature of interaction with structures. Damage can be more extensive than with the same mass of high explosive, even though the latter may have a higher peak pressure. It is the purpose of this study to examine the air-blast characteristics of reactive- and inert-binder propellants as compared to each other and with those of conventional high explosive.

The 8-inch-diameter test specified in "Explosives Hazard Classification Procedure", Department of the Army Technical Bulletin TB 700-2, 31 July 1962, has been performed on 17 propellant formulations. Peak side-on overpressure and side-on impulse as a function of distance have been determined and related to that of an equivalent amount of TNT.

(U) Section II. DATA ACQUISITION

Peak side-on overpressure and side-on impulse are measured at a maximum of 10 locations per shot. Gauge stations are arranged in 3 radial arrays 120° apart at distances from 40 to 80 feet, in 5-foot increments, from ground zero (Figures 1 and 2). Pressure and impulse are measured with Kistler[2] 603A quartz pressure transducers in conjunction with Kistler 553B charge amplifiers. The outputs of these gauges are passed through preamplifiers and recorded on a 14-channel Honeywell[3] 7700 magnetic tape recorder. The data as recorded on the magnetic tape are retrieved with the use of a Consolidated Electrodynamics[4] 5-124 oscillograph. Overpressure is determined by the ratio of the linear measure of the amplitude of the resulting oscillograph trace of the pressure gauge response to the linear measure of the amplitude of the trace generated by a known voltage. The tape recorder is run continuously during the time the calibration voltages are applied and the shot is fired. One direct record channel is used to monitor the timing of the event. A zero time pulse is recorded as voltage is applied to the firing circuit, and the subsequent time increments are used in the determination of time of arrival and impulse of the blast wave. Impulse is determined by measuring pressures at convenient equal time increments and integrating by the trapezodial method. The mathematical manipulations are performed by computer. A more detailed account of the data acquisition procedure is given in Reference 1. Photographic coverage of each event is provided by a Fairchild[5] camera at a framing rate of approximately 3000 f/s; a time-mark generator is used to place timing marks on the film.

---

[2]Kistler Instrument Corp., 8989 Sheridan Dr., Clarence, N. Y.

[3]Honeywell, Denver Division, 4800 Dry Creek Rd., Denver, Colo.

[4]Consolidated Electrodynamics Corp., 360 Sierra Madre Villa, Pasadena, Calif.

[5]Fairchild Camera and Instrument Corp., 88-06 Van Wyck Expressway, Jamaica, N. Y.

(U) Section III. SHOOTING PROCEDURE

Photographs are taken of all charges, appropriate labels, and resulting witness plates during the setup and firing of the shot; typical examples are shown in Figures 3, 4, 5, and 6. These photographs are useful in record keeping since the labels are photographed at the time the shot is fired and the "menu board" serves as an unambiguous standard to connect the shot number with the labels and the resulting witness plate. As can be seen in Figures 4 and 5, the 8-inch-diameter by 32-inch-long propellant charge is fired in the vertical position. An 8-inch-diameter by 24-inch-long conical pentolite donor (FSN 1375-991-8893) is placed in contact with the upper propellant surface and fired with an Engineer Special Electric Blasting Cap. A 1 × 12 × 12 inch witness plate is placed in contact with the lower propellant surface to determine if the propellant charge undergoes detonation; the punching of a clean hole in the witness plate, as in Figure 6, is taken as evidence of a detonation. The test item is supported 18 inches above the firing pad by an open ended wood stand; the vermiculite used to pack the donor charge is poured into the wood stand to a depth of 12-14 inches in an effort to minimize damage to the steel firing pad. In retrospect, the use of the vermiculite seems futile since the firing pad was destroyed during the series of shots reported herein.

The pressure gauges are placed in the appropriate locations. Ideally each gauge should be placed in a location which will result in an almost full-scale deflection of the oscillograph galvanometer; however, care must be taken not to saturate the channel, else the pressure cannot be determined. One must therefore estimate the overpressure at each gauge location so that the recording of the pressures can be optimized. Usually nine channels of data are taken per shot with 5 gauges placed in one leg and 2 each in the other 2 legs.

Immediately after each shot the witness plate is examined to determine if the propellant charge detonated. The temperature and barometric pressure are recorded at the time each shot is performed.

(U) Section IV. RESULTS

Blast-wave data have been obtained on 17 propellant formulations. TNT, and pentolite donors on dummy charges, Table I. All of the propellant charges were 8-inch diameter by 32-inches long and were initiated with 8 inch diameter pentolite donors. The non-detonable propellant charges were steel confined; the detonable propellants were confined only by $\frac{3}{16}$-inch cellulose acetate or cardboard casting cans. The 100-lbm TNT charge consisted of a stack of 1-lbm demolition charges with overall dimensions of 7.5 X 9.5 X 35.5 in. A standard 8-inch-diameter pentolite charge was used to initiate the TNT, (124 lbm total). Dummy charges were made by filling two 8-inch-diameter by 32-inch-long Schedule 40 water pipe with sand; these charges were initiated in the usual manner. The overpressure and impulse data for TNT, Table II and Figures 7 and 8, and pentolite donors, Table III and Figures 9 and 10, can then be used as baseline data. The former is taken to be a 100% TNT acceptor and the latter is taken to be a 0% TNT acceptor. An overpressure vs. reduced distance (2) plot was made for the 100-lbm TNT and dummy shots with the result that the TNT equivalent, based on overpressure, of pentolite is 100, Table III and Figure 11. It is interesting to note the damage to the pipe and witness plate for the case of the dummy acceptor; the pipe is "banana peeled" and the witness plate is dented, Figures 12 and 13. Perhaps the extent of denting of the witness plate is accentuated in this event since an 8-inch-diameter pipe was used for a stand (rather than a wood box), making a sort of punch and die arrangement.

The manufacturer's designations for the propellant compositions fired during the present shot series are given in Table IV. All of the propellant charges were 1600 cu. inches. (8-inch diameter by 32 inch long; a nominal propellant density of 0.063 lb/cu. inch is taken which results in an active propellant mass of 100 lb for each round. This approximation is well within the experimental scatter of the over-pressure and impulse data observed; the overpressure is a function of the cube root of the mass (2); therefore an error of 10% in the mass results in an error of less than 4% in the cube root of the mass. Furthermore, by considering each round to be 100 lbm the data reduction is straightforward. Each resulting overpressure vs. distance curve for each propellant round is compared directly with the corresponding curve for TNT. A curve is drawn through the points by visual inspection, and this average curve is compared with a similar

one taken from the corresponding TNT data. A TNT equivalent is then calculated from the average values at distances at 40, 50, 60, 70, and 80 feet based on overpressure and impulse.

Points which obviously fall outside reasonable statistical limits are discarded, and on occasions when points fall consistently low, or high, on successive shots from the same pressure gauge they are also discarded, (e.g. gauge station A40 in shots 126, 127, 128, and 129). The discarded data points are so noted in the tables.

In the calculation of impulse a pressure-time trace is divided into equal time increments such that 30-50 points are obtained for the computer input. A comparison was made on one pressure-time trace (shot 117, gauge station B45) where it was found that 50 μsec time increments, 211 points, resulted in an impulse of 67.4 psi-msec while 500 μsec time increments, 22 points, resulted in an impulse of 70.5 psi-msec. It was therefore concluded that 30-50 points were adequate for the present impulse data reduction.

The peak side-on overpressures and side-on impulses are given in Tables V-XXI and Figures 14-47, for the propellant compositions given in Table IV.

The TNT equivalents reported in Tables V-XXI are not on as firm a footing as one would like since they are based on only one unconfined detonation of a TNT charge. But since all the propellants reported herein are related to the same TNT calibration, any comparison made between propellants is valid. It must be remembered, however, that the range in which the data were taken is relatively small and should not be extrapolated to long or short distances. It may be that the curves could converge, diverge, or cross at longer reduced distances than those observed here. It is felt that more shots, and thus more data points, for each propellant would not alter the conclusions to any significant degree. It is nevertheless felt that one shot per formulation is not sufficient. As an example, shots 136 and 137 would have had a different TNT equivalent if they had been analyzed separately even though the rounds were made from the same batch of RH-P-112 propellant. In a case such as this additional rounds are warranted.

A calculation of overpressure by time of arrival data (2) does not show any significant improvement over the present method. The arrival times have nevertheless been recorded in the tables and are

useful in confirming that the pressure traces have not become confused during the rather complicated recording and read out procedures, e. g. shot 138.

(U) Section V. CONCLUSIONS

Equivalence based on TNT is not a straightforward concept. The TNT equivalent of a propellant formulation may vary with distance, charge size, and stimulus. In the present study it has been found that the TNT equivalent of non-detonable propellants varies from 55 to 85 and that of detonable propellants varies from 100 to 140 depending upon the formulation. The TNT equivalent appears to be a function of distance, but with the present data the experimental scatter somewhat obscures this point. The TNT equivalent based on peak side-on overpressure is in general the same as the TNT equivalent based on side-on impulse, but again the experimental scatter precludes a definite conclusion.

In regard to the use of data obtained by the method employed in the present study or by similar methods, one must remember that the stimulus given to the propellant acceptor does not apply to probable stimuli given to end items as they are used. The TNT equivalent determined by having a large high-explosive donor in contact with the propellant is an extreme case rather than a realistic one.

(U) Section VI. RECOMMENDATIONS FOR FUTURE WORK

There are several areas where future work should be directed, as follows:

1. Shoot future shots from bottom up rather than top down. This will most probably prolong the life of the firing pad.

2. Obtain more data on TNT, confined as well as unconfined, so that a proper datum line can be drawn.

3. Obtain data on high explosives such as Composition C-4 in a similar geometry.

4. Examine TNT equivalent as a function of input stimulus.

5. Examine TNT equivalent as a function of formulation, burning rate, specific impulse, density, density impulse, and other ballistic parameters.

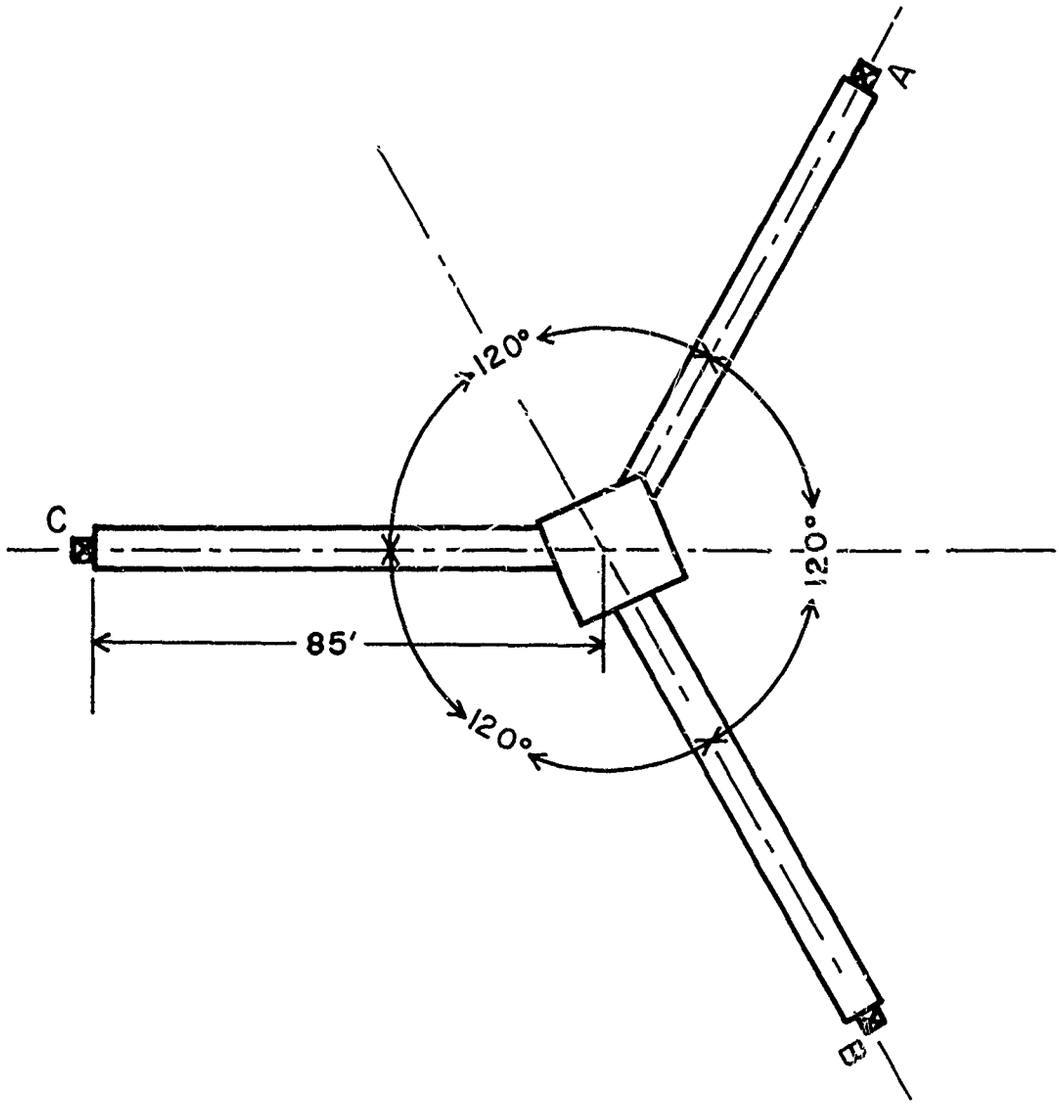

FIGURE 1. PHYSICAL LAYOUT OF RANGE

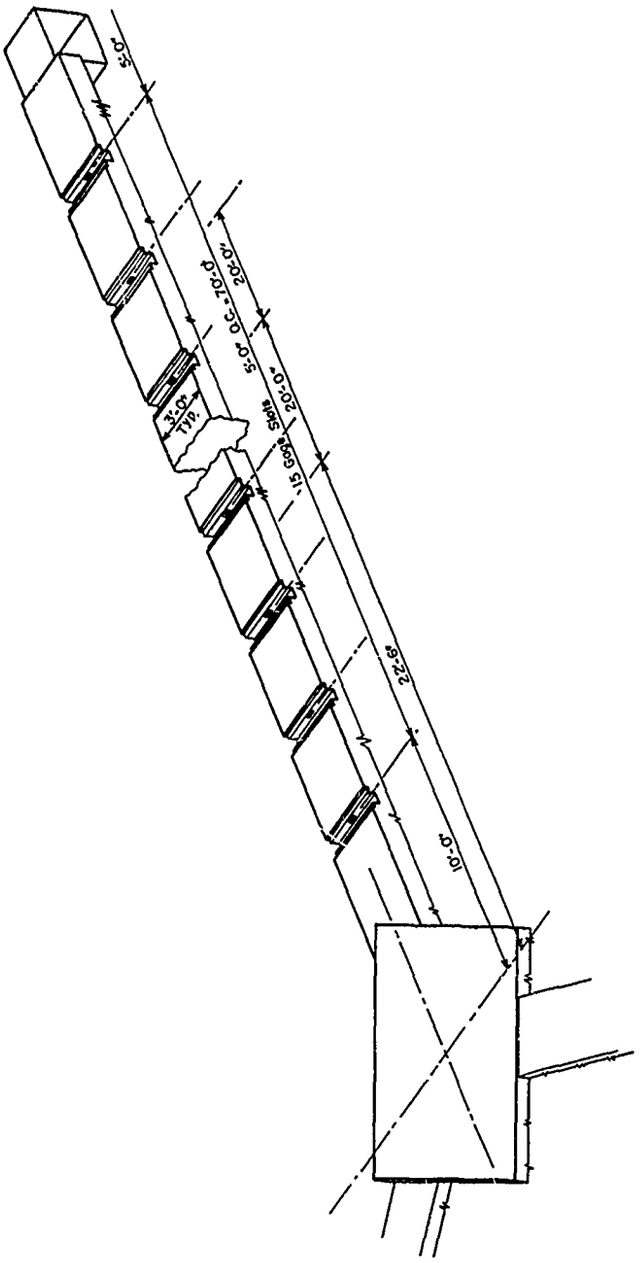

FIGURE 2. DETAIL OF INSTRUMENTATION ARRAYS

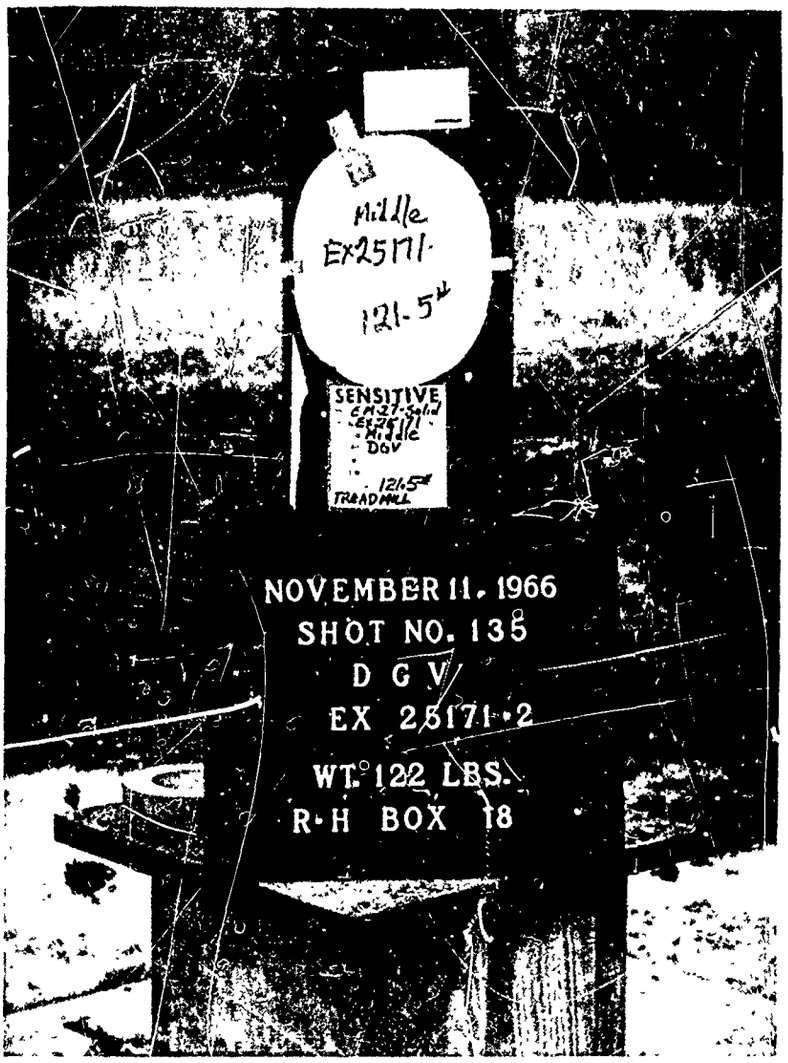

FIGURE 3. TYPICAL PHOTOGRAPH OF PROPELLANT ROUND AND LABELS BEFORE FIRING

FIGURE 4. TYPICAL PHOTOGRAPH OF PROPELLANT ROUND AND DONOR BEFORE FIRING

FIGURE 5. PHOTOGRAPH OF ARMED ROUND BEFORE FIRING

FIGURE 6. TYPICAL PHOTOGRAPH OF WITNESS PLATE SHOWING DETONATION OF PROPELLANT CHARGE

Table I. Firing Range Data

Shot	Acceptor Designation	Confinement	Temp. °F	Witness Plate
105	Dummy	Steel pipe		no
108	TP-H-7022	3/4 in. steel	74	no
109	ANP-3196	5/16 in. steel	74	no
110	ANP-3146	5/16 in. steel	78	no
115	Dummy	Steel pipe		no
117	DQV	3/16 in. cellulose acetate	74	go
118	FAE	3/16 in. cellulose acetate	78	go
119	EJD	3/16 in. cellulose acetate	80	go
120	DGV	3/16 in. cellulose acetate	81	go
121	ARP	3/16 in. cellulose acetate	78	go
122	ANP-2969	5/16 in. steel	78	no
123	C-129	5/16 in. steel	76	no
124	TP-H-7020	3/4 in. steel	77	no
125	ANP-3066	3/4 in. steel	78	no
126	TP-H-7028	3/4 in. steel	78	no
127	ANB-3119	3/4 in. steel	78	no
128	ANB-3123	3/4 in. steel	80	no
129	ANB-3127	3/4 in. steel	82	no
131	DQV	3/16 in. cellulose acetate	68	go
132	FAE	3/16 in. cellulose acetate	73	go
133	ARP	3/16 in. cellulose acetate	74	go
134	EJD	3/16 in. cellulose acetate	58	go
135	DGV	3/16 in. cellulose acetate	61	go
136	RH-P-112	Cardboard	60	go
137	RH-P-112	Cardboard	60	go
138	ANP-3146	5/16 in. steel	66	no
139	ANP-3066	5/16 in. steel	58	no
140	ANP-2969	5/16 in. steel	64	no
141	ANP-3196	5/16 in. steel	67	no
142	C-129	5/16 in. steel	58	no
143	TNT	Stacked 1 lbm tins	69	go

Table II. Blast Wave Data for TNT

Leg	r	p	i	t
B	40	20.0	47.6	13.4
B	50	8.7	37.5	19.7
B	60	6.1	28.2	27.0
B	70	4.5	30.5	34.6
B	80	3.0	24.0	42.7
A	50	15.2	51.4	21.9
A	80	5.6	16.3	43.7
C	50	12.9	36.4	22.0
C	80	6.2	27.4	36.4

r	p	i
40	22.0	47.5
50	12.3	37.0
60	8.3	30.0
70	5.8	26.0
80	4.1	23.5

Definitition of Parameters with Units:

r radial distance, feet
p peak side-on overpressure, psig
i side-on impulse, psi-msec
t arrival time, msec

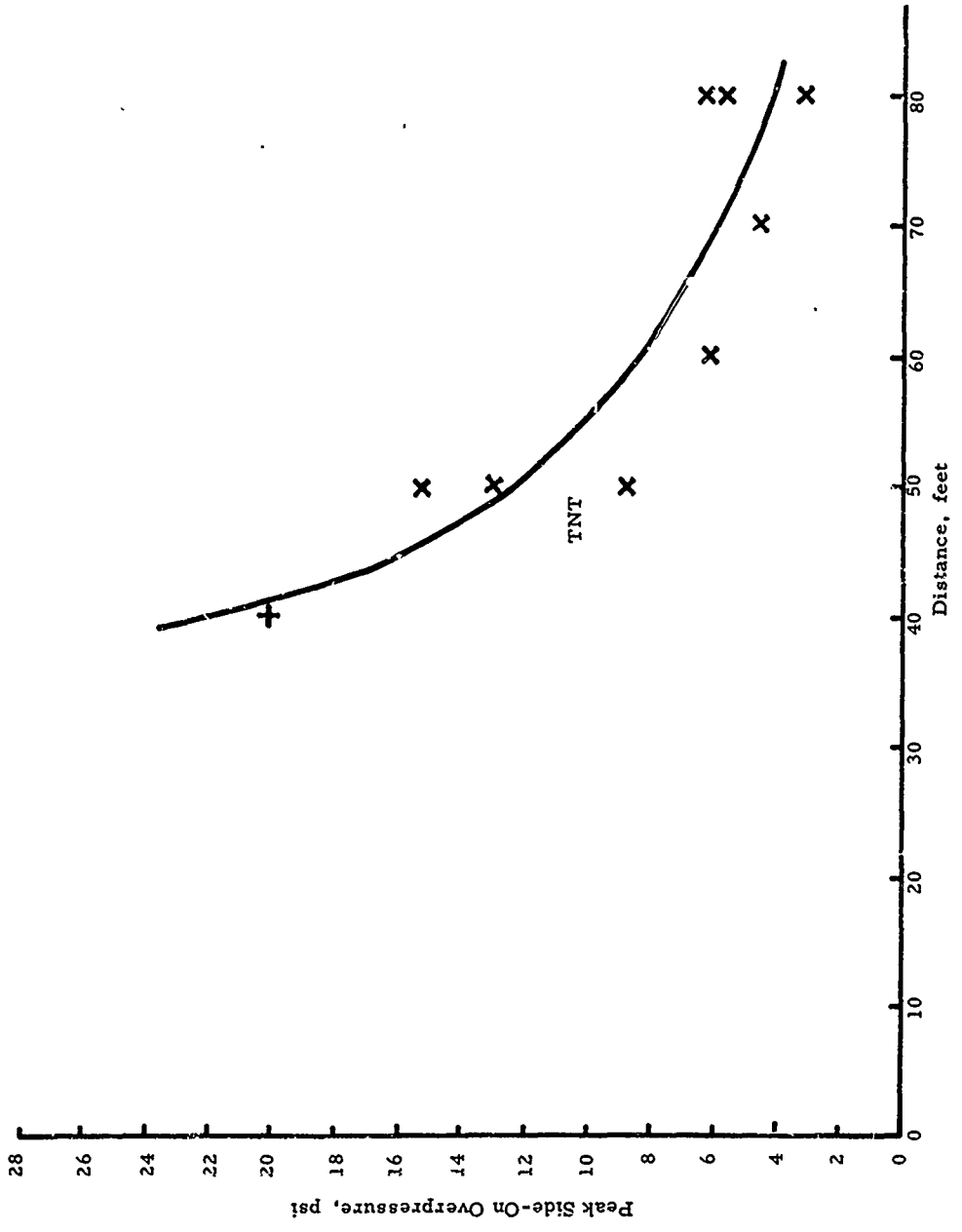

FIGURE 7. PEAK SIDE-ON OVERPRESSURE VS. DISTANCE FOR 100 LBM TNT INITIATED WITH 24 LBM PENTOLITE

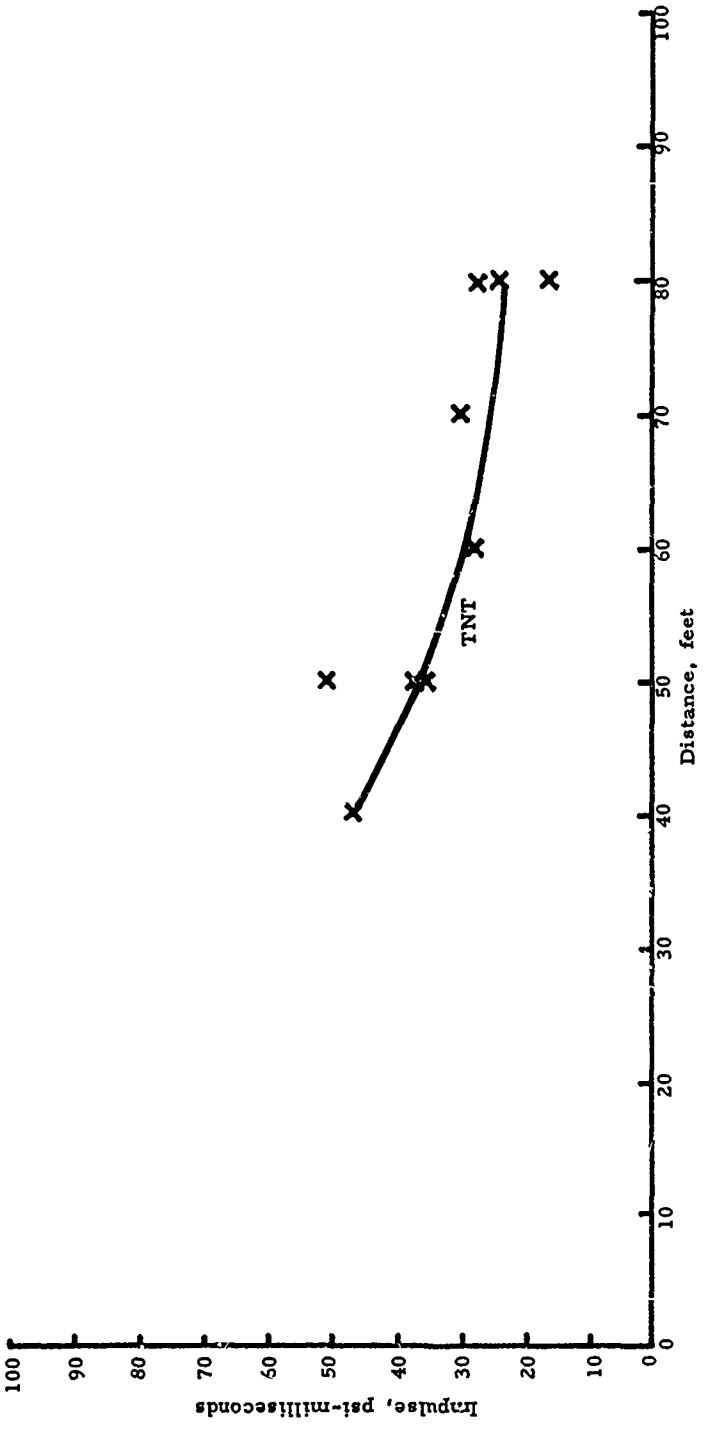

FIGURE 8. SIDE-ON IMPULSE VS. DISTANCE FOR 100 LBM TNT INITIATED WITH 24 LBM PENTOLITE

Table III. Blast Wave Data for Pentolite Donors on Dummy Acceptors

Leg	r	p	i	t	Leg	r	p	i	t
A	25	15.9	28.7	11.5	A	25	17.7	27.6	11.7
A	30	12.5	25.6	14.8	A	30	11.1	24.8	15.0
A	40	7.0	18.4	21.9	A	40	6.4	18.0	22.2
A	70	1.9	9.5	45.5	A	70	1.9	9.8	46.0
A	80	1.8	8.3	53.7	A	80	1.6	8.6	54.2
B	30	11.4	27.6	14.6	B	30	12.4	25.5	14.4
B	40	6.8	20.8	21.7	B	40	6.1	18.2	21.5
C	30	13.4	25.9	15.0	C	30	12.0	25.7	14.7
C	40	7.0	18.1	21.0	C	40	7.8	19.0	21.8

Reduced Quantities

Pentolite			TNT + Pentolite		
r	p	λ	r	p	λ
25	16.8	8.6	40	22.0	8.0
30	12.1	10.4	50	12.3	10.0
40	6.7	13.9	60	8.3	12.0
70	1.9	24.3	70	5.8	14.0
80	1.7	27.8	80	4.1	16.0

r radial distance, feet
p peak side-on overpressure, psig
i side-on impulse, psig-msec
t arrival time, msec
λ reduced distance, $r/w^{1/3}$, feet/$(lbs)^{1/3}$

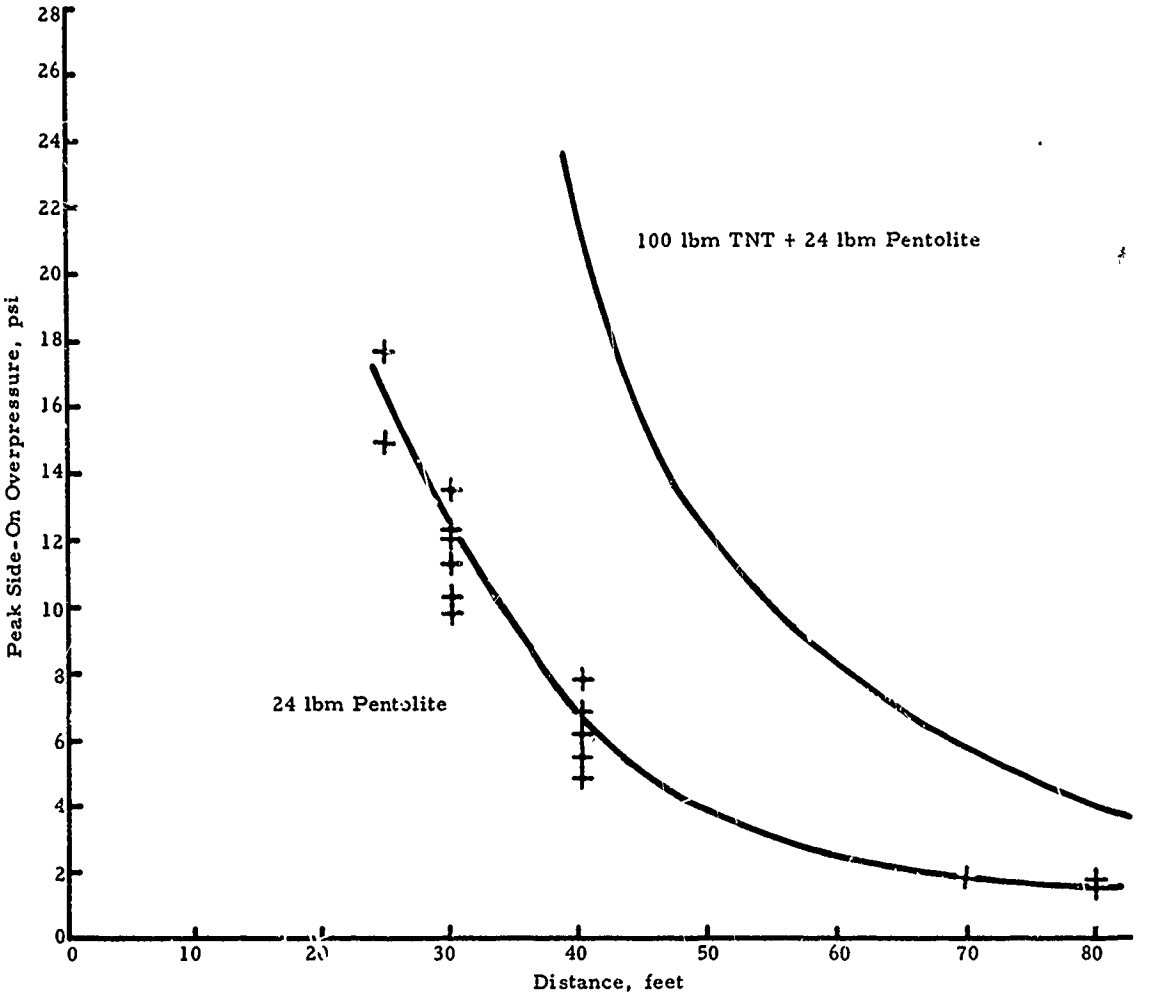

FIGURE 9. COMPARISON OF PEAK SIDE-ON OVERPRESSURES GENERATED BY 100% AND 0% ACCEPTOR CHARGES

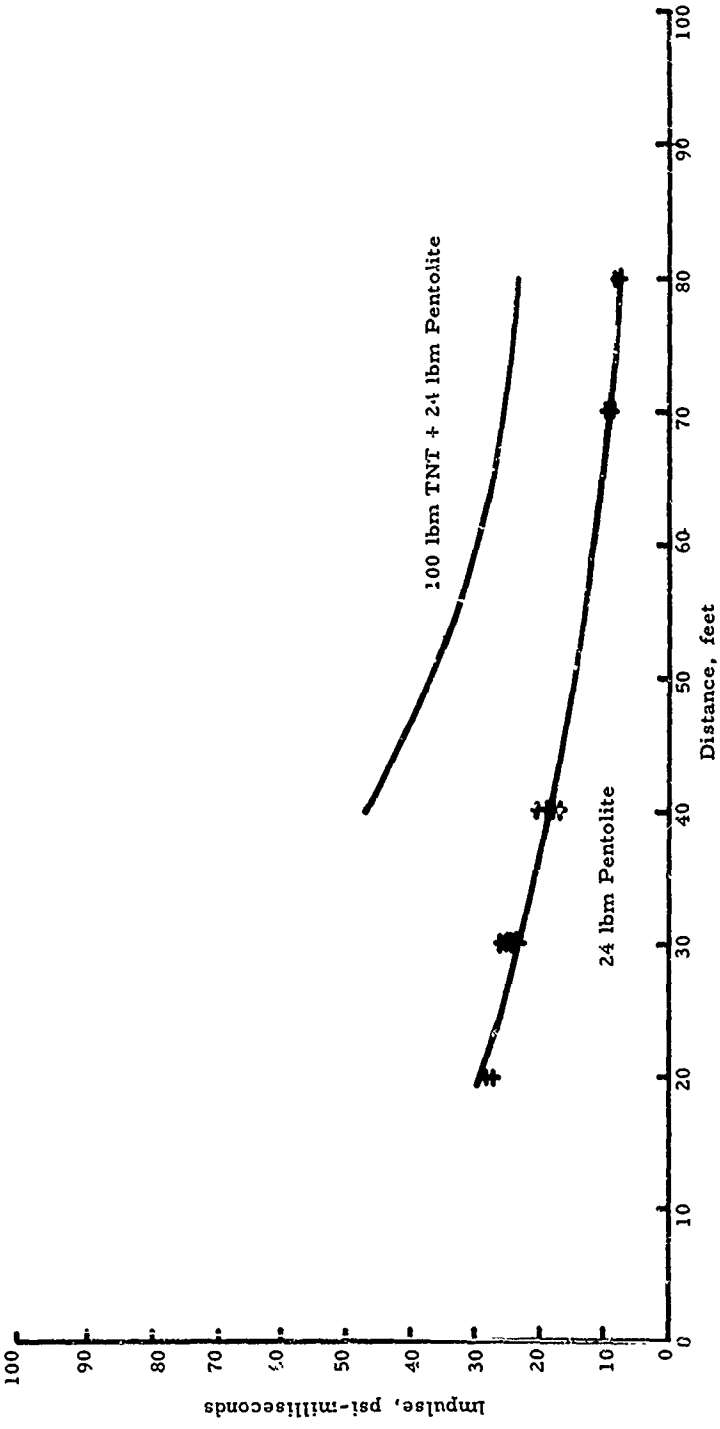

FIGURE 10. COMPARISON OF SIDE-ON IMPULSE GENERATED BY 100% AND 0% ACCEPTOR CHARGES

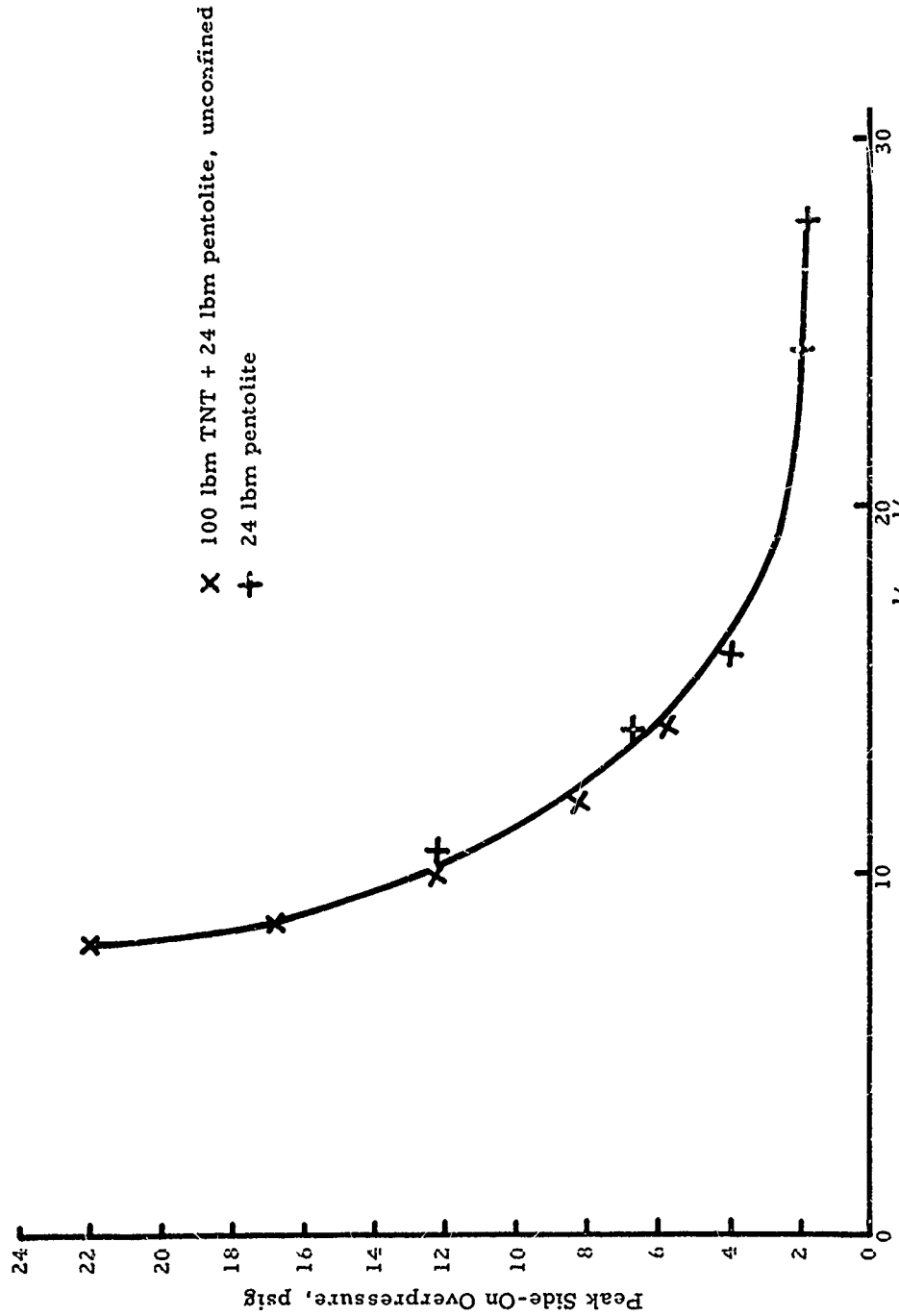

FIGURE 11. PEAK SIDE-ON OVERPRESSURE VS. REDUCED DISTANCE FOR 100% AND 0% REFERENCE SHOTS

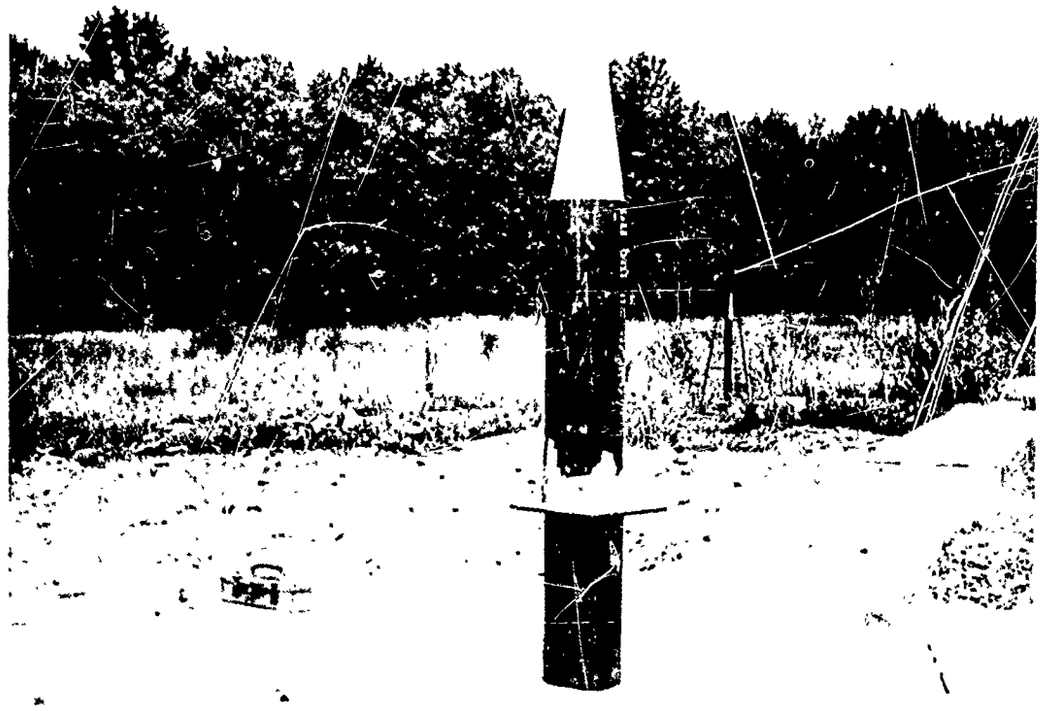

FIGURE 12. PENTOLITE DONOR ON DUMMY CHARGE BEFORE FIRING

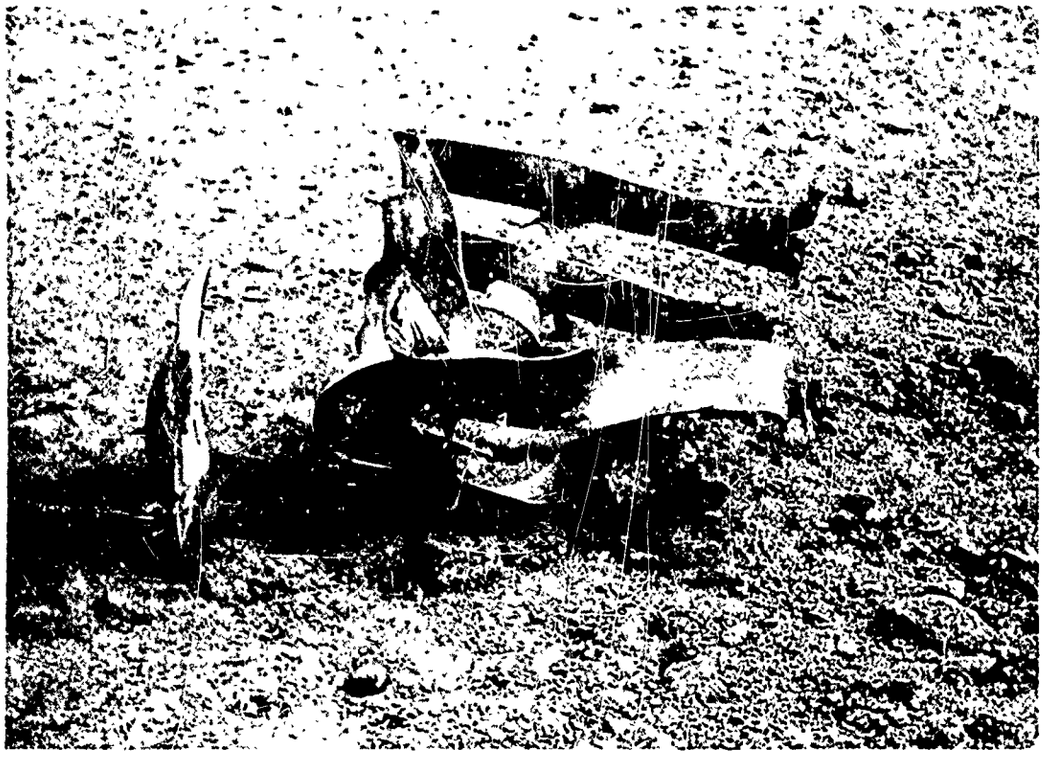

FIGURE 13. WITNESS PLATE AND PIPE RESULTING FROM PENTOLITE DONOR ON DUMMY CHARGE

Table IV. Manufacturers' Designations of Propellants

Propellant	Manufacturer's Designation
	Hercules Incorporated
ARP	Grain No. EX-25177, Base grain-middle
	Grain No. EX-25279, Base grain-middle
DGV	Grain No. EX 27173-2, Base grain ZI 65 B1
	Grain No. EX-25171-2, Base grain-middle
DQV	Grain No. EX-25268, Base grain 2312D.28B
	Grain No. EX-25269, Base grain 2312D.28B, middle
EJD	Grain No. EX-25175, Base grain ZI-221
	Grain No. EX-25174-2, Base grain ZI-221
FAE	Grain No. EX-25227, Base grain ZI-257
	Grain No. EX-25225, Base grain ZI-257
	Aerojet General Corporation
ANB-3119	63-4160 #101, 8703-07-101
ANB-3123	63-4162 #102, 8708-07-101
ANB-3127	63-4163 #103
ANP-2969	Batch CM-1334 Pot 59, Polaris
	Batch CM-133Y-59, Polaris
ANP-3066	9-3066-DW-M-2, Grain No. 8, Minuteman
	9-3066-DW-M-2, Grain No. 9, Minuteman
ANP-3146	55D-B-007, HIP Booster
	55D-B-007, HIP Booster
ANP-3196	55D-S-006, HIP Sustainer
	55D-S-006, Grain No. 4, HIP Sustainer
C-129	First $\frac{2}{3}$, cast w/bayonet from C-129, Top, 41
	Batch No. C-129, Grain No. C, 1500
	Thiokol Chemical Corporation
TP-H-7020	2-K-702
	440-28-15
TP-H-7022	2J-2658
	375-22-16
TP-H-7028	1-J-2669
	365-21-28
	Rohm and Haas Company
RH-P-112	Batch 2002
	Batch 2002

Table V Blast-Wave Data for ARP Propellant

Shot 121					Shot 133				
Leg	r	p	i	t	Leg	r	p	i	t
A	40	21.4	54.8	14.2	B	40	22.7	48.2	14.8
A	45	14.6	47.4	17.2	B	50	11.3	29.8[a]	21.1
A	60	8.0	35.2	27.4	B	60	7.8	31.6	28.1
A	70	6.3	27.4	34.7	B	70	6.0	27.5	35.5
A	80	5.0	25.0	42.3	B	80	4.0	23.8	43.3
B	45	16.9	45.6	17.1	A	50	13.8	51.2[a]	21.3
B	60	8.1	35.4	27 3	C	50	12.6	39.2	21.0
C	45	16.0	46.1	17.4	C	70	5.6	26.8	35.5
C	60	8.2	36.6	27.6					

	ARP Avg.		TNT Avg.		TNT Equivalent	
r	p	i	p	i	Ep	Ei
40	22.0	53.0	22.0	47.5	100	112
50	12.3	41.5	12.3	37.0	100	112
60	8.3	33.5	8.3	30.0	100	112
70	5.8	27.5	5.8	26.0	100	110
80	4.1	24.5	4.1	23.5	100	105

Definition of Parameters with Units:

- r radial distance, feet
- p peak side-on overpressure, psig
- i side-on impulse, psi-msec
- t arrival time, msec
- Ep TNT equivalent based on overpressure, per cent
- Ei TNT equivalent based on impulse, per cent

Footnotes:

[a] Discarded points.

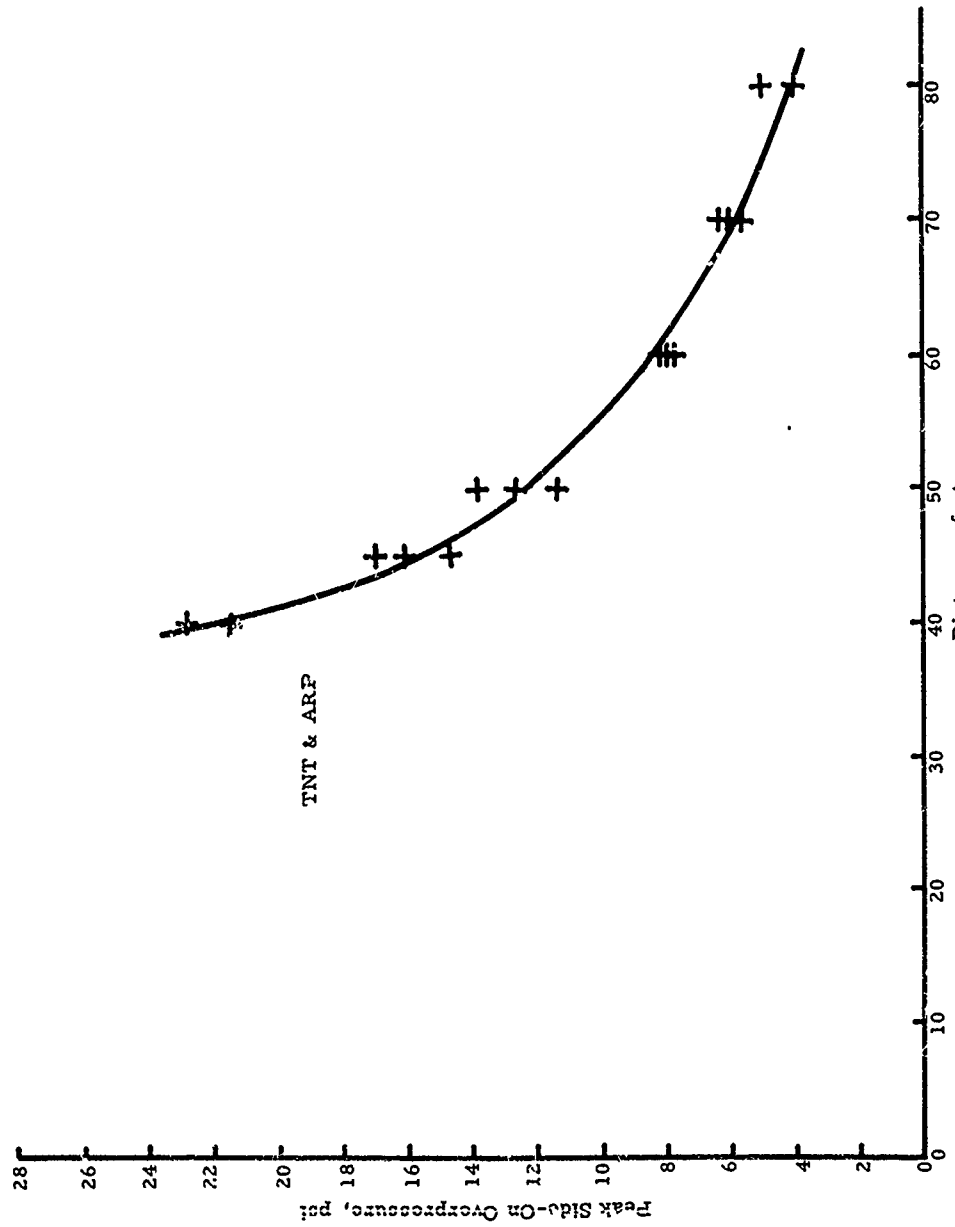

FIGURE 14. PEAK SIDE-ON OVERPRESSURE VS. DISTANCE FOR ARP PROPELLANT AND TNT

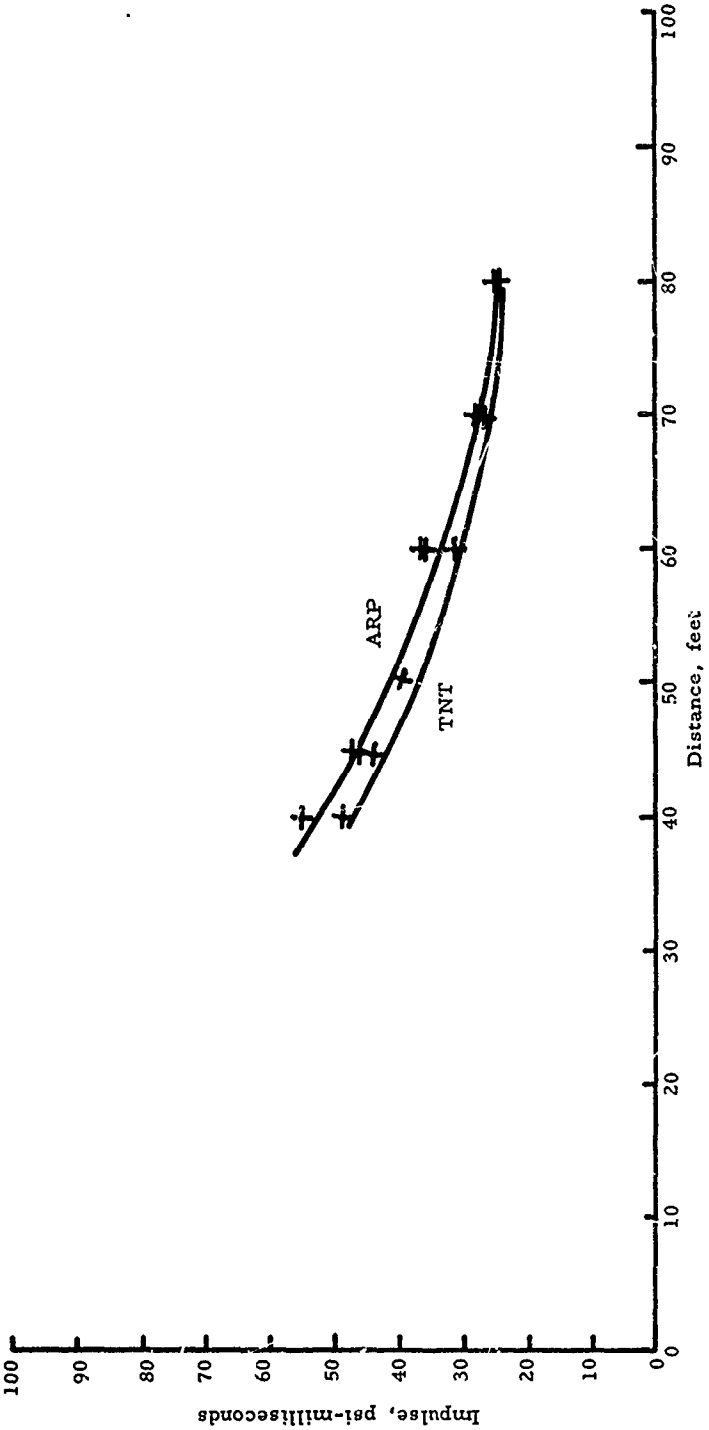

FIGURE 15. SIDE-ON IMPULSE VS. DISTANCE FOR ARP PROPELLANT AND TNT

Table VI. Blast-Wave Data for DGV Propellant

Shot 120					Shot 135				
Leg	r	p	i	t	Leg	r	p	i	t
A	40	26.3	66.5	12.8	B	40	25.8	54.9	13.4
A	45	17.6	62.4	15.7	B	50	20.1	59.3	19.6
A	60	9.0	40.1	25.7	B	60	9.6	27.5[a]	26.2
A	70	6.8	40.1	32.9	B	70	7.8	32.5	33.4
A	80	5.1	29.1	40.4	B	80	3.4	20.6	41.1
B	45	24.8	58.3	15.4	A	50	15.6	56.2	19.4
B	60	9.4	42.1	25.3	A	80	5.2	22.2	41.0
					C	50	5.5[a]	17.8[a]	19.4
					C	70	7.1	36.2	33.5

	DGV Avg.		TNT Avg.		TNT Equivalent	
r	p	i	p	i	Ep	Ei
40	27.5	64.5	22.0	47.5	125	136
50	15.9	54.0	12.3	37.0	129	146
60	10.6	43.0	8.3	30.0	127	143
70	6.6	33.5	5.8	26.0	114	129
80	4.8	25.0	4.1	23.5	117	107

Definition of Parameters with Units:

r	radial distance, feet
p	peak side-on overpressure, psig
i	side-on impulse, psi-msec
t	arrival time, msec
Ep	TNT equivalent based on overpressure, per cent
Ei	TNT equivalent based on impulse, per cent

Footnotes:

[a] Discarded points.

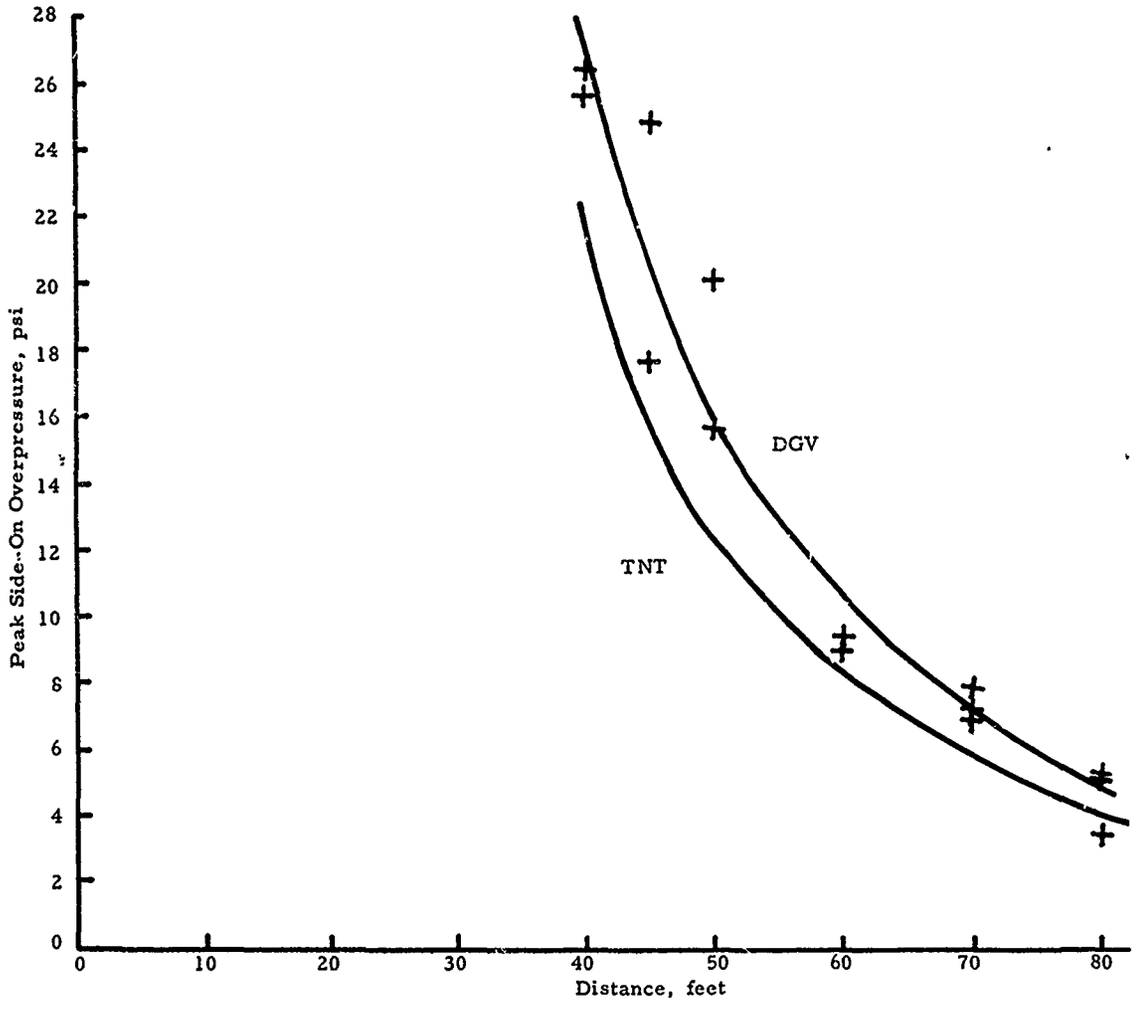

FIGURE 16. PEAK SIDE-ON OVERPRESSURE VS. DISTANCE FOR DGV PROPELLANT AND TNT

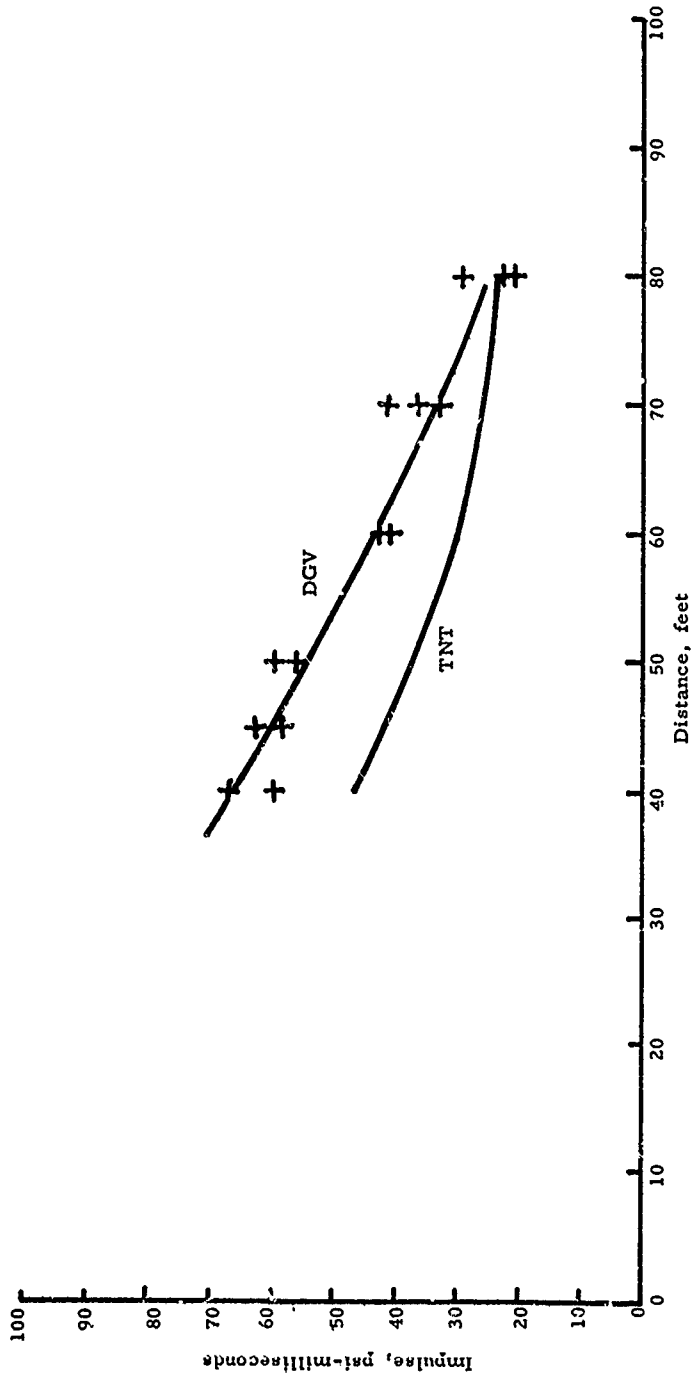

FIGURE 17. SIDE-ON IMPULSE VS. DISTANCE FOR DGV PROPELLANT AND TNT

Table VII. Blast-Wave Data for DQV Propellant

Shot 117					Shot 131				
Leg	r	p	i	t	Leg	r	p	i	t
A	40	23.3	80.3	13.1	B	40	17.2[a]	61.4[a]	13.0
A	45	20.8	59.6	16.0	B	50	16.5	42.5	19.2
A	60	9.5	40.1	25.8	B	60	9.3	37.4	25.9
A	70	6.8	34.4	32.9	B	70	8.0	36.8	33.2
A	80	5.1	27.8	40.5	B	80	3.5	19.7	40.9
B	45	17.1	70.5	15.9	A	50	25.2[a]	87.5[a]	19.1
B	60	9.0	44.2	25.8	A	80	3.2	15.9	40.8
C	45	23.5	55.1	15.6	C	50	13.7	47.6	19.1
C	60	9.1	43.9	25.5	C	70	7.0	33.1	33.3

	DQV Avg.		TNT Avg.		TNT Equivalent	
r	p	i	p	i	Ep	Ei
40	26.4	71.0	22.0	47.5	120	150
50	14.9	53.5	12.3	37.0	121	145
60	9.5	41.0	8.3	30.0	115	137
70	6.4	33.5	5.8	26.0	110	129
80	4.4	27.0	4.1	23.5	107	115

Definition of Parameters with Units:

r	radial distance, feet
p	peak side-on overpressure, psig
i	side-on impulse, psi-msec
t	arrival time, msec
Ep	TNT equivalent based on overpressure, per cent
Ei	TNT equivalent based on impulse, per cent

Footnotes:

[a] Discarded points.

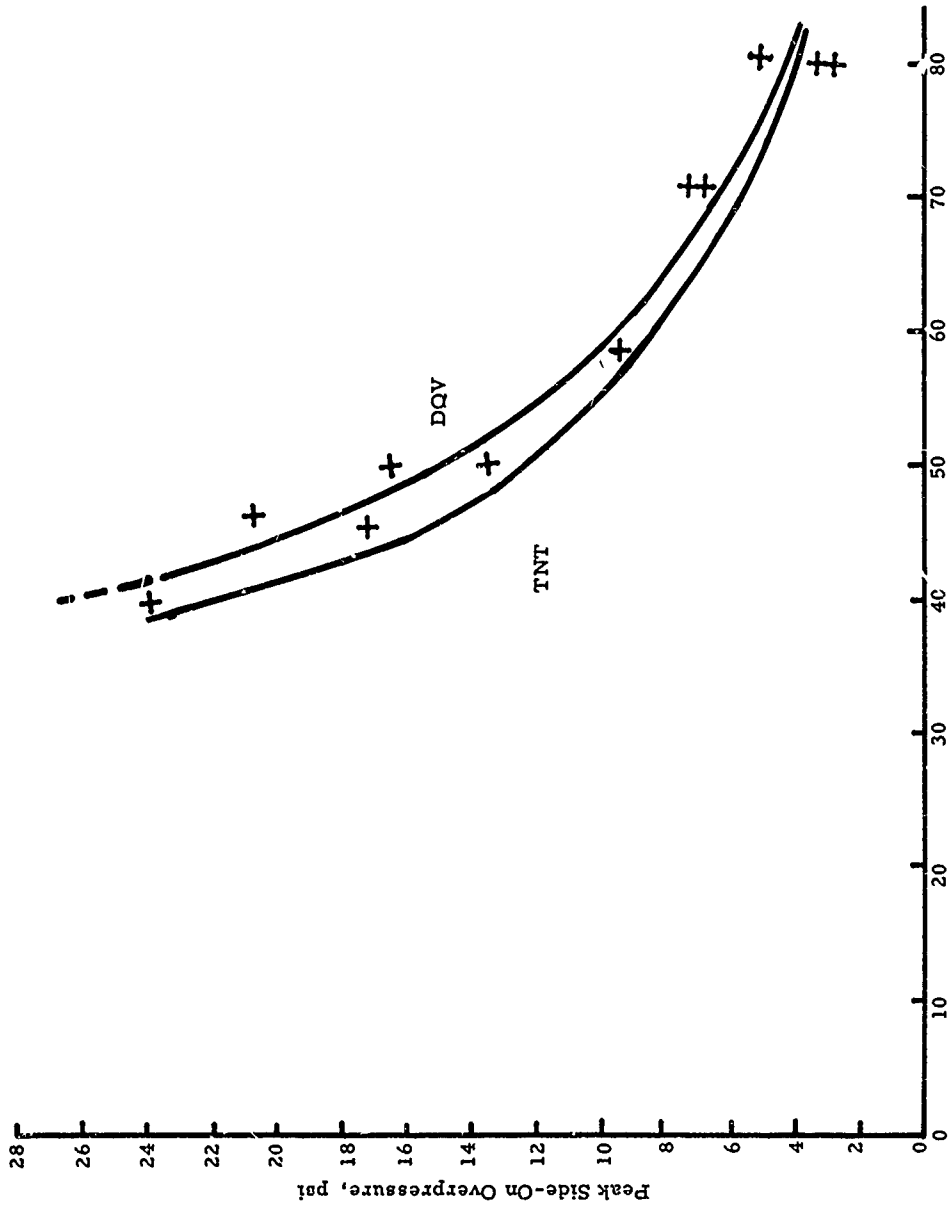

FIGURE 18. PEAK SIDE-ON OVERPRESSURE VS. DISTANCE FOR DQV PROPELLANT AND TNT

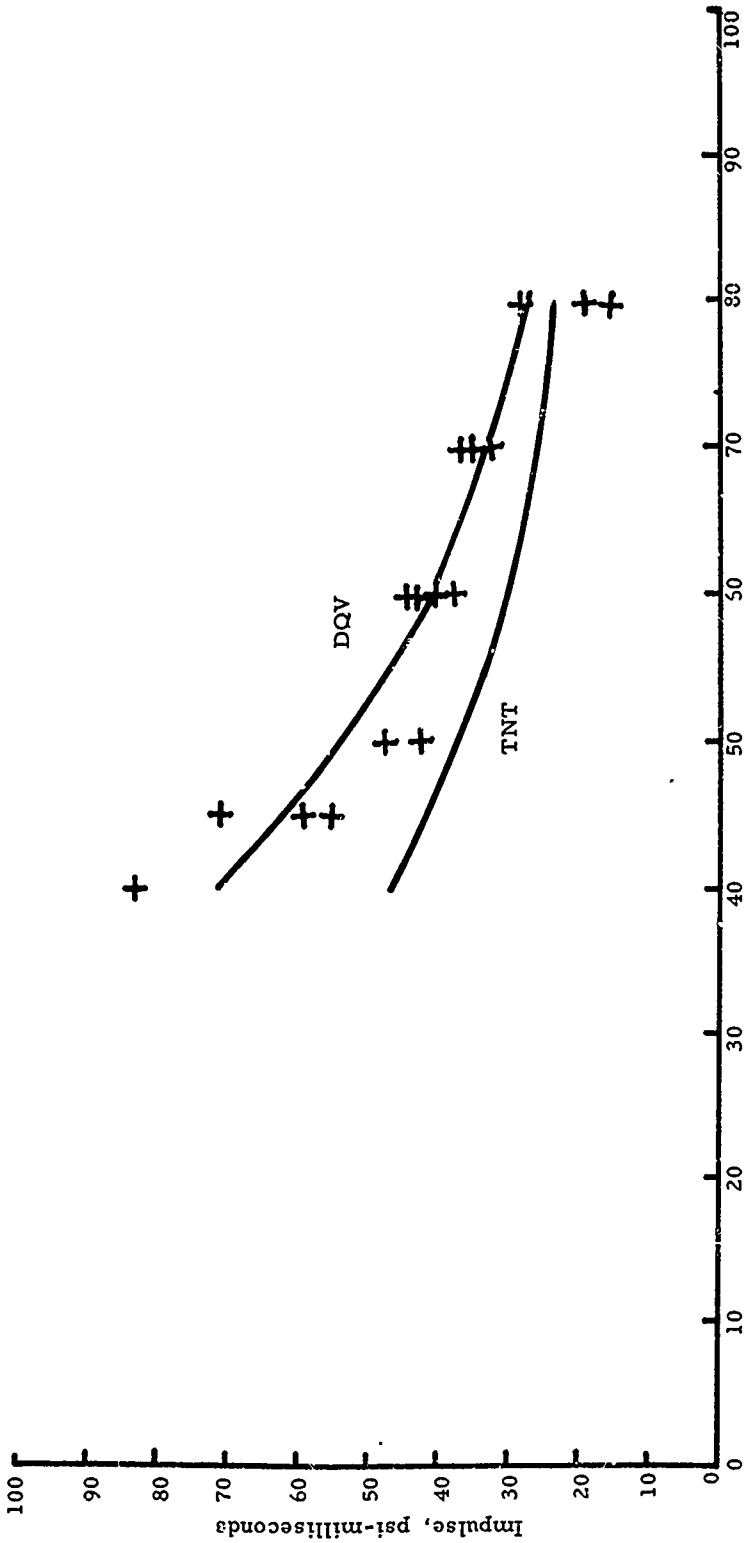

FIGURE 19. SIDE-ON IMPULSE VS. DISTANCE FOR DQV PROPELLANT AND TNT

Table VIII. Blast-Wave Data for EJD Propellant

Shot 119					Shot 134				
Leg	r	p	i	t	Leg	r	p	i	t
A	40	26.6	65.0	12.5	B	40	27.5	69.0	12.7
A	45	16.5	68.7	15.4	B	50	13.2	40.4[a]	18.7
A	60	9.7	41.8	25.3	B	60	9.4	43.2	25.6
A	70	7.5	39.2	32.4	B	70	7.3	32.9	32.8
A	80	5.0	32.2	40.0	A	50	15.3	60.8	19.2
B	45	9.6	61.8	14.6	C	50	14.1	43.6[a]	19.0
B	60	7.6	40.6	25.3	C	70	7.1	34.4	33.2
C	45	8.4	55.2	14.7					

	EJD Avg.		TNT Avg.		TNT Equivalent	
r	p	i	p	i	Ep	Ei
40	26.6	66.5	22.0	47.5	121	140
50	14.6	54.0	12.3	37.0	119	146
60	9.9	44.5	8.3	30.0	119	148
70	7.3	36.5	5.8	26.0	126	140
80	5.0	29.5	4.1	23.5	122	126

Definition of Parameters with Units:

- r radial distance, feet
- p peak side-on overpressure, psig
- i side-on impulse, psi-msec
- t arrival time, msec
- Ep TNT equivalent based on overpressure, per cent
- Ei TNT equivalent based on impulse, per cent

Footnotes:

[a] Discarded points.

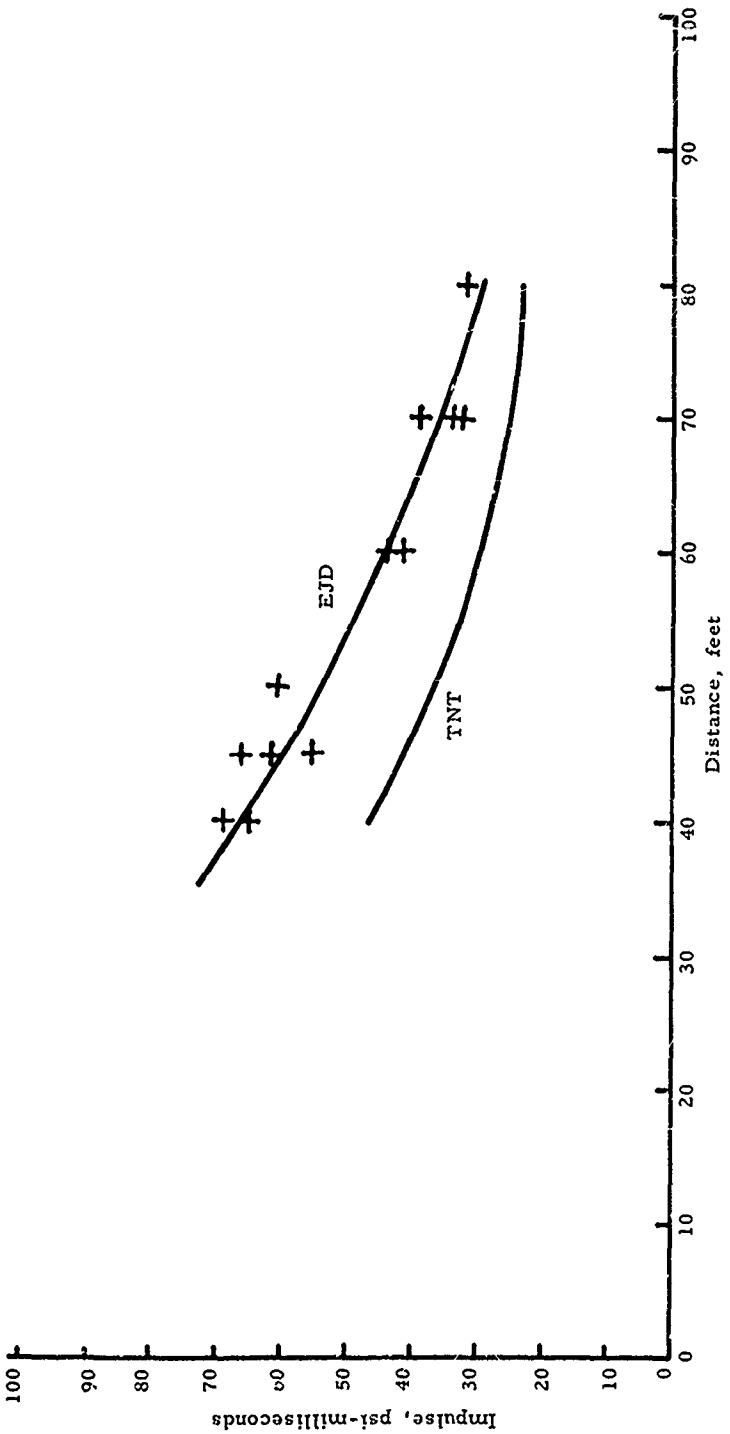

FIGURE 20. PEAK SIDE-ON OVERPRESSURE VS. DISTANCE FOR EJD PROPELLANT AND TNT

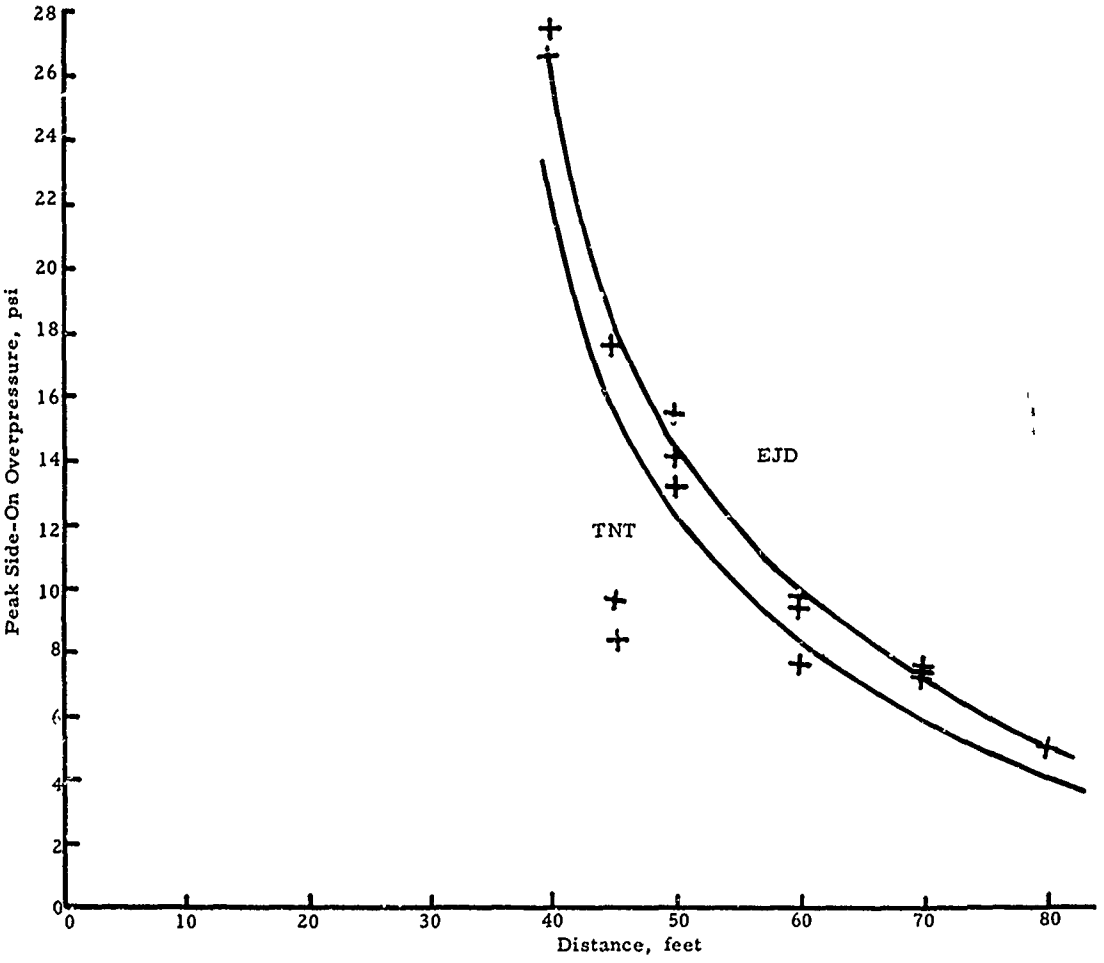

FIGURE 21. SIDE-ON IMPULSE VS. DISTANCE FOR EJD PROPELLANT AND TNT

Table IX. Blast-Wave Data for FAE Propellant

Shot 118					Shot 132				
Leg	r	p	i	t	Leg	r	p	i	t
A	40	14.5	55.0	12.2	B	40	22.9	51.4	14.0
A	45	9.3	47.8	15.1	B	50	14.5	42.0	20.1
A	60	6.4	40.7	26.1	B	60	9.2	38.1	26.8
A	70	5.6	32.1	33.5	B	70	7.0	33.7	34.1
A	80	4.8	27.7	40.1	B	80	4.8	28.1	41.8
B	60	9.0	39.3	26.2	A	50	15.7	61.2[a]	20.3
C	45	18.0	52.2	16.4	A	80	5.3	26.6	41.9
C	60	9.4	37.0	26.4	C	50	14.7	43.0	20.2
					C	70	6.1	29.9	34.4

	FAE Avg.		TNT Avg.		TNT Equivalent	
r	p	i	p	i	Ep	Ei
40	---	55.0	22.0	47.5		116
50	---	45.0	12.3	37.0		122
60	---	37.5	8.3	30.0	~100	125
70	---	31.5	5.8	26.0		121
80	---	28.0	4.1	23.5		119

Definition of Parameters with Units:

r	radial distance, feet
p	peak side-on overpressure, psig
i	side-on impulse, psi-msec
t	arrival time, msec
Ep	TNT equivalent based on overpressure, per cent
Ei	TNT equivalent based on impulse, per cent

Footnotes:

[a] Discarded points.

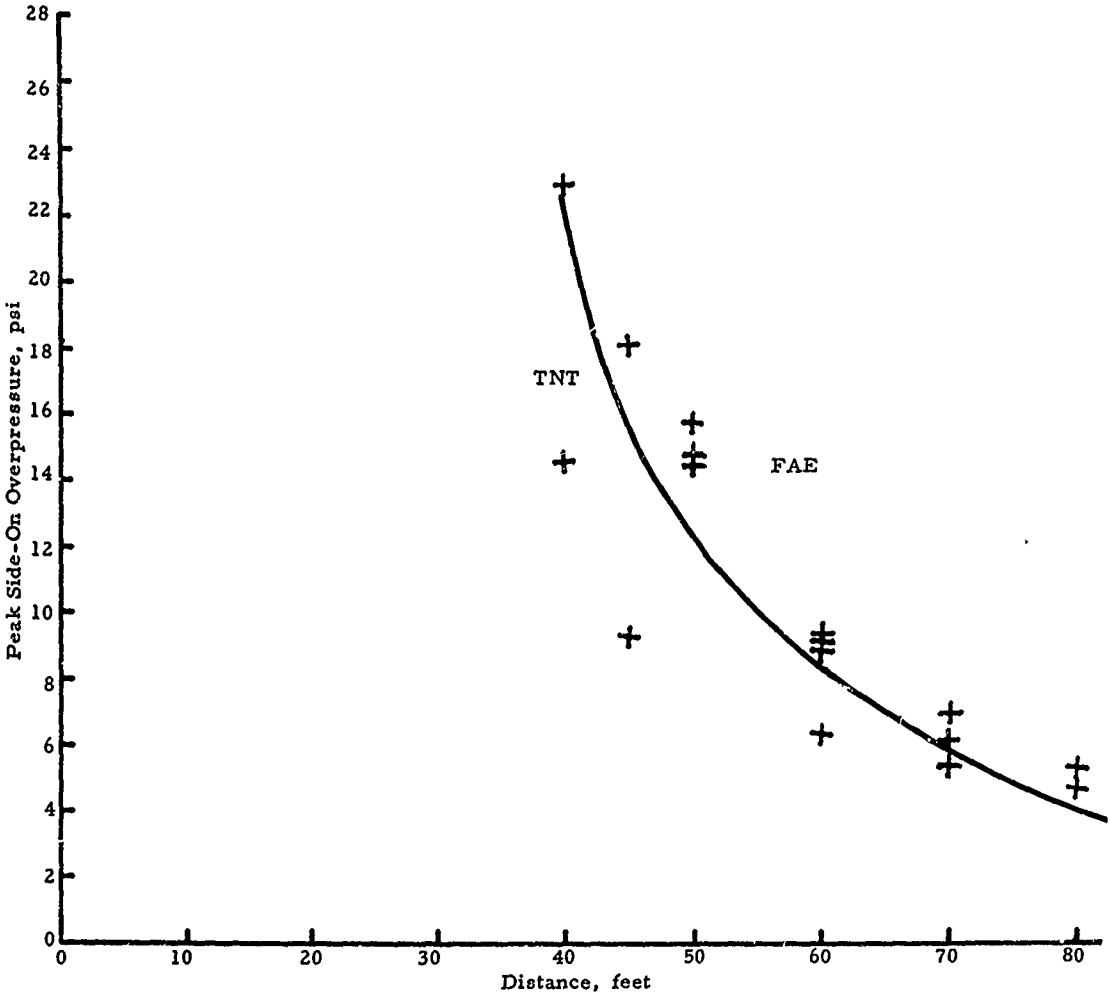

FIGURE 22. PEAK SIDE-ON OVERPRESSURE VS. DISTANCE FOR FAE PROPELLANT AND TNT

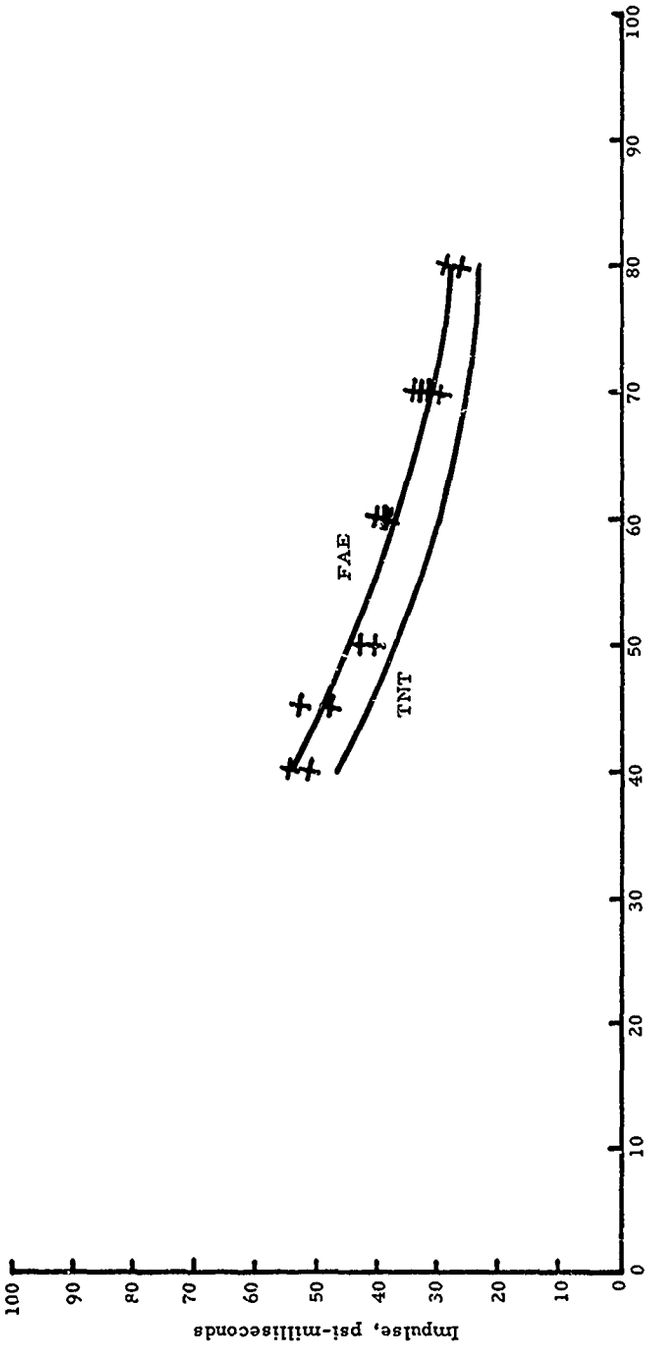

FIGURE 23. SIDE-ON IMPULSE VS. DISTANCE FOR FAE PROPELLANT AND TNT

Table X. Blast-Wave Data for ANB-3119 Propellant

Shot 127

Leg	r	p	i	t
A	40	10.0[a]	35.0	19.3
A	45	10.6	33.9	22.8
A	60	5.9	26.5	33.7
A	70	3.2	15.2	41.4
A	80	2.2	14.2	49.3
B	45	13.6	34.2	22.4
B	60	4.7	24.2	33.3
C	45	10.6	33.6	22.4
C	60	3.5	26.1	33.4

	ANB-3119 Avg.		TNT Avg.		TNT Equivalent	
r	p	i	p	i	Ep	Ei
40	13.8	41.0	22.0	47.5	63	86
50	8.2	30.5	12.3	37.0	67	83
60	4.9	23.5	8.3	30.0	59	78
70	3.2	18.5	5.8	26.0	55	71
80	2.2	15.5	4.1	23.5	54	66

Definition of Parameters with Units:

- r radial distance, feet
- p peak side-on overpressure, psig
- i side-on impulse, psi-msec
- t arrival time, msec
- Ep TNT equivalent based on overpressure, per cent
- Ei TNT equivalent based on impulse, per cent

Footnotes:

[a] Discarded points.

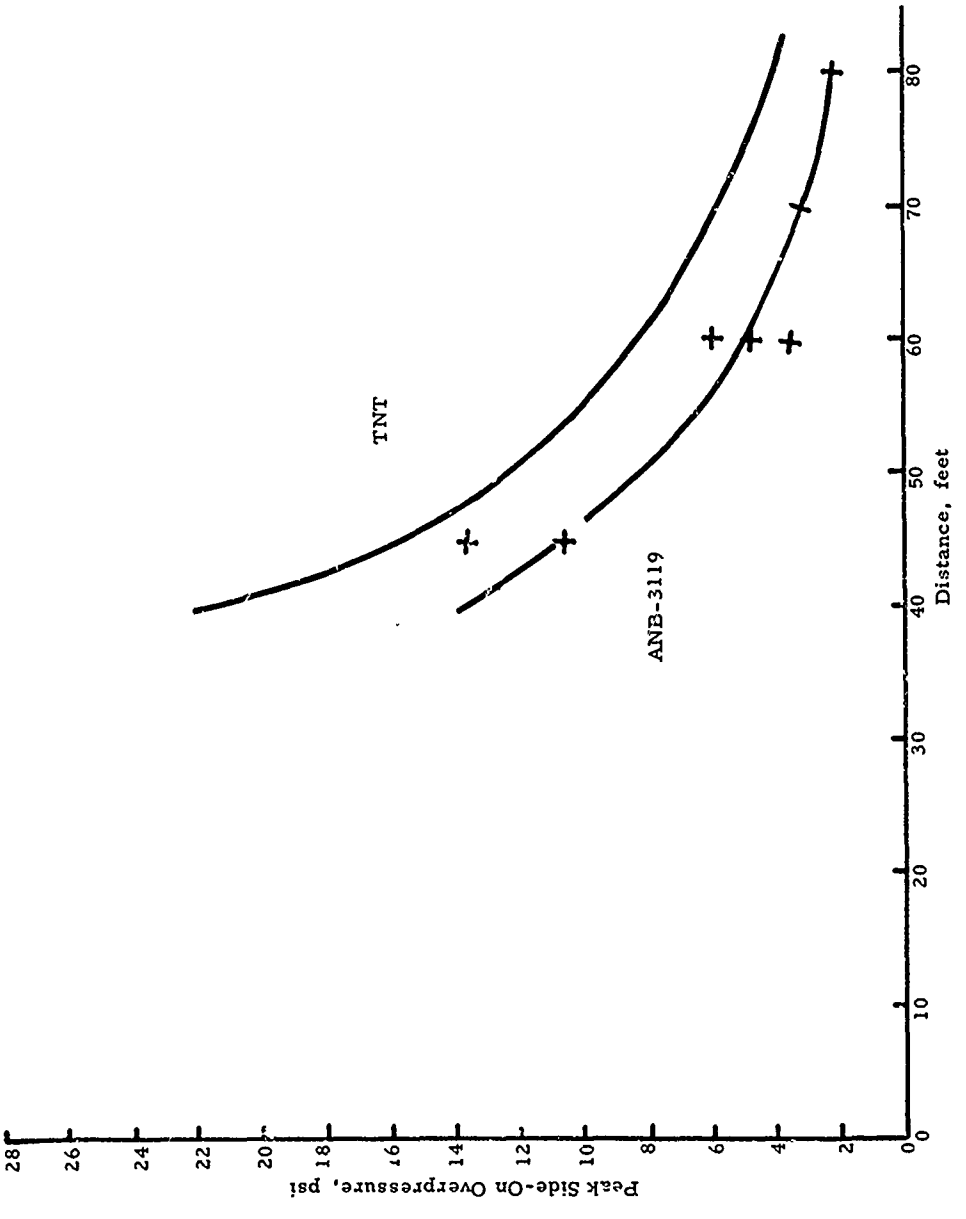

FIGURE 24. PEAK SIDE-ON OVERPRESSURE VS. DISTANCE FOR ANB-3119 PROPELLANT AND TNT

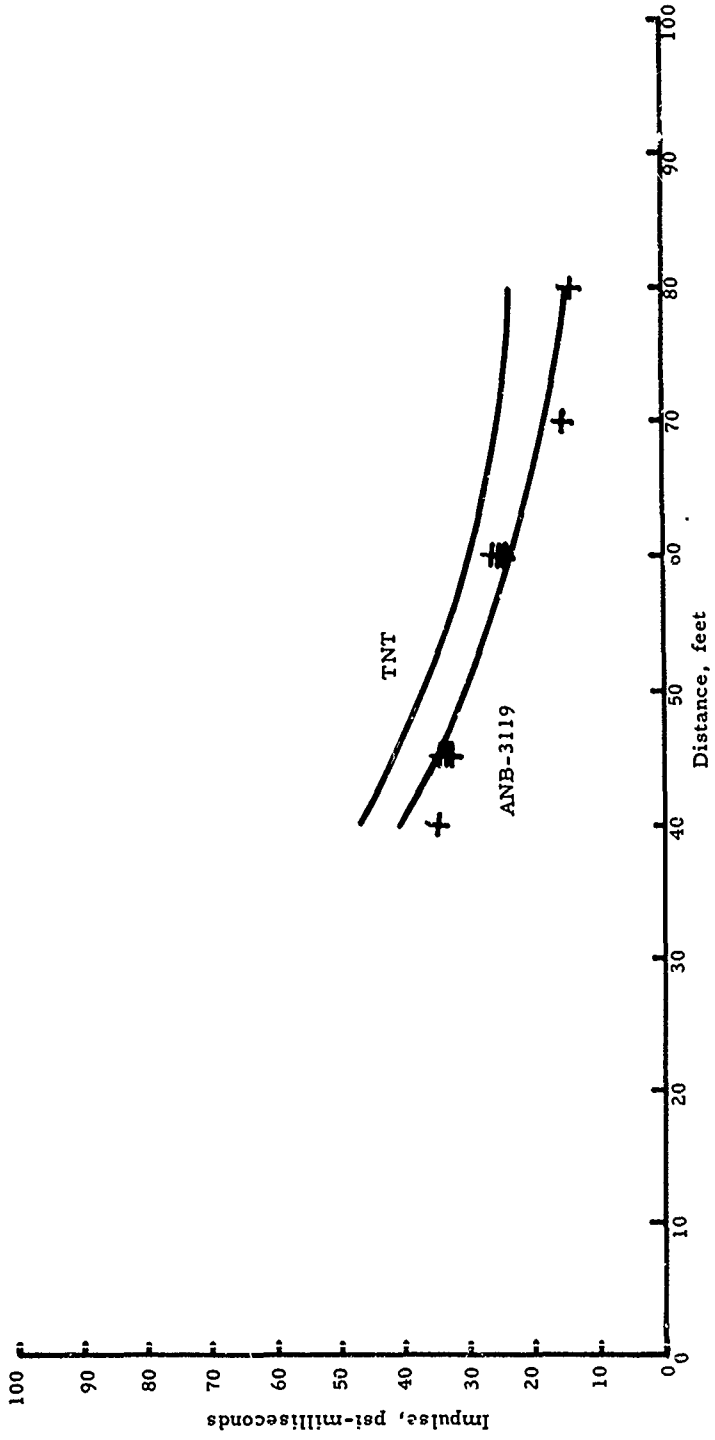

FIGURE 25. SIDE-ON IMPULSE VS. DISTANCE FOR ANB-3119 PROPELLANT AND TNT

Table XI. Blast-Wave Data for ANB-3123 Propellant

Shot 128

Leg	r	p	i	t
A	40	10.9[a]	36.9	18.6
A	45	10.9	34.1	21.9
A	60	6.0	27.6	32.7
A	70	4.2	22.5	40.4
B	45	14.2	36.9	21.9
B	60	6.6	24.2	32.8
C	45	14.1	34.6	21.7
C	60	3.1[a]	24.0	32.5

	ANB-3123 Avg.		TNT Avg.		TNT Equivalent	
r	p	i	p	i	Ep	Ei
40	14.6	40.0	22.0	47.5	66	84
50	9.3	32.0	12.3	37.0	76	86
60	6.3	26.0	8.3	30.0	75	87
70	4.2	22.5	5.8	26.0	72	87
80	2.9	20.0	4.1	23.5	71	89

Definition of Parameters with Units:

- r radial distance, feet
- p peak side-on overpressure, psig
- i side-on impulse, psi-msec
- t arrival time, msec
- Ep TNT equivalent based on overpressure, per cent
- Ei TNT equivalent based on impulse, per cent

Footnotes:

[a] Discarded points.

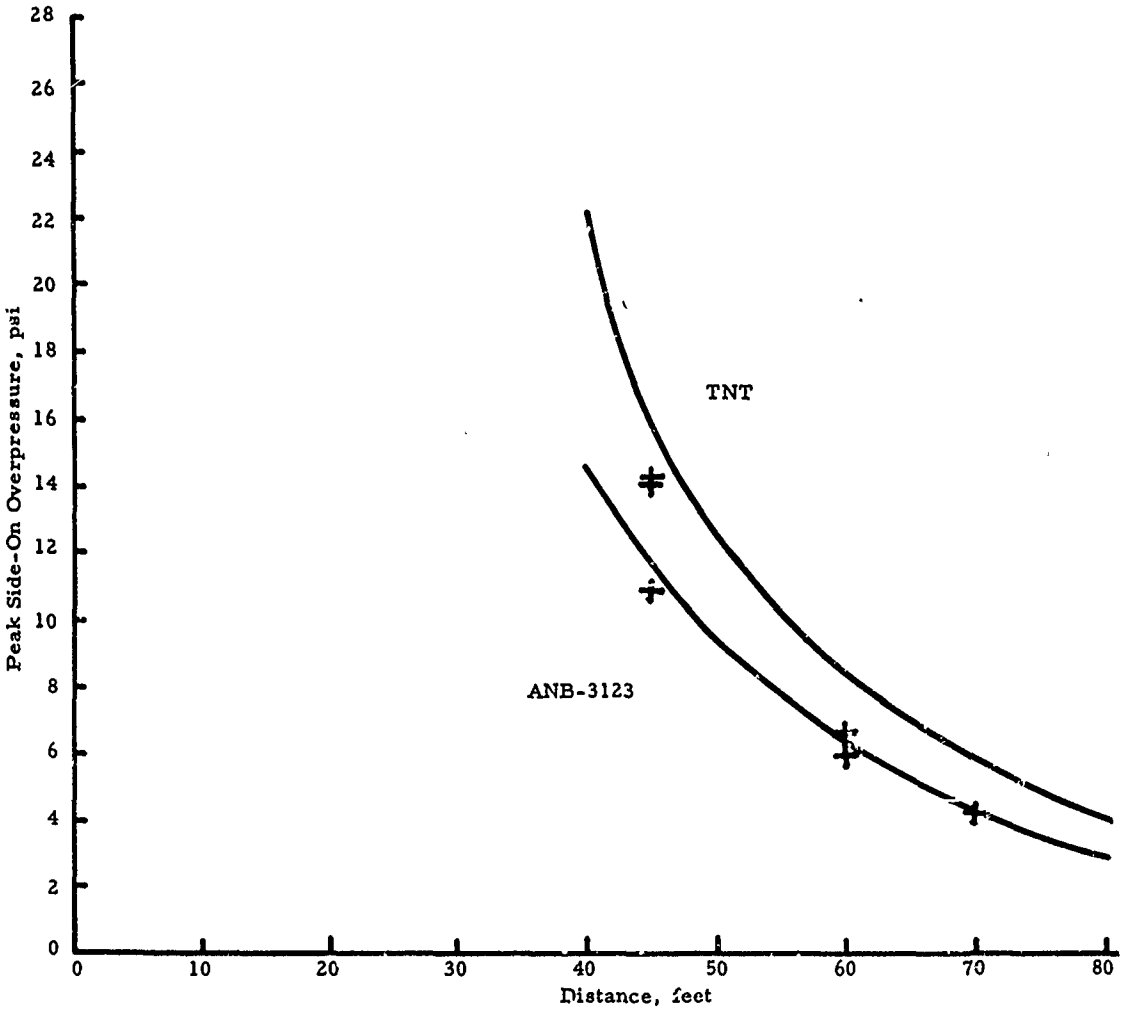

FIGURE 26. PEAK SIDE-ON OVERPRESSURE VS. DISTANCE FOR ANB-3123 PROPELLANT AND TNT

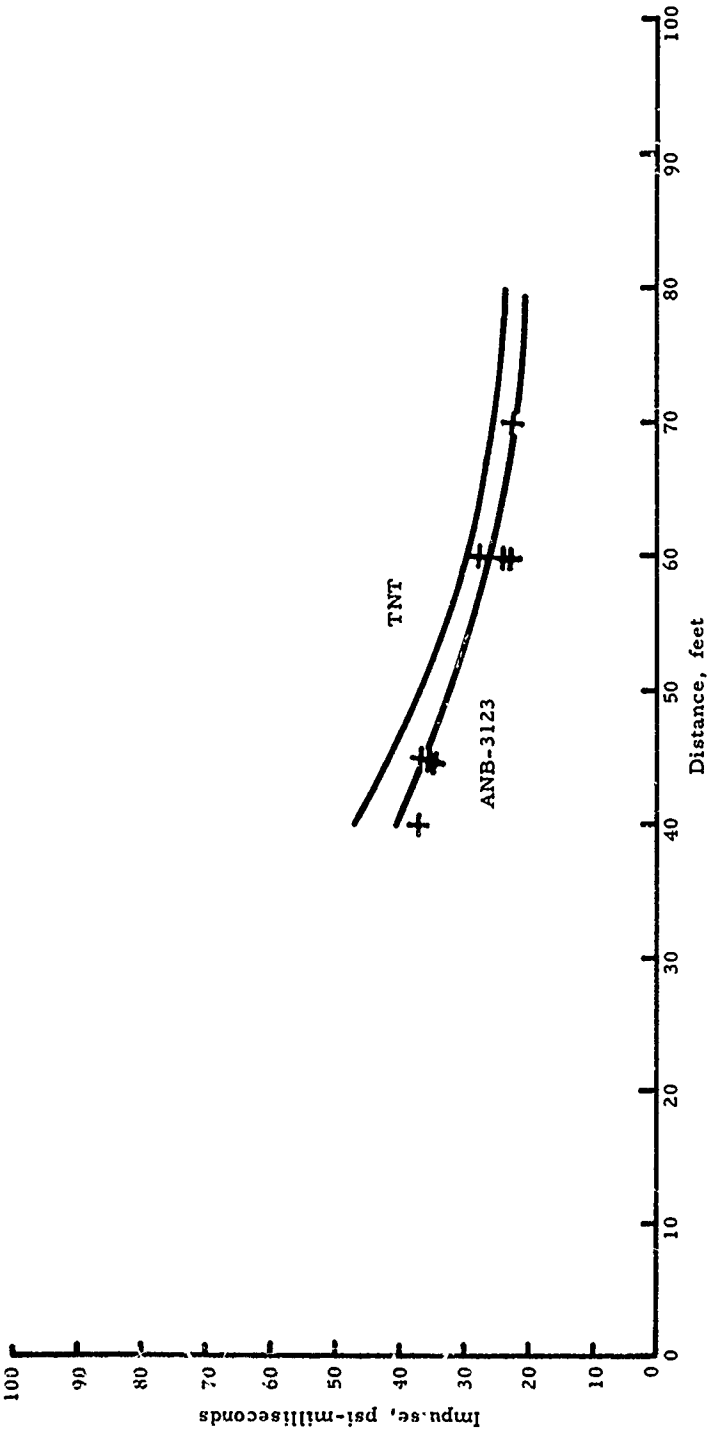

FIGURE 27. SIDE-ON IMPULSE VS. DISTANCE FOR ANB-3123 PROPELLANT AND TNT

Table XII. Blast-Wave Data for ANB-3127 Propellant

Shot 129

Leg	r	p	i	t
A	40	10.4[a]	38.0	18.3
A	45	11.9	35.2	21.7
A	60	7.4	25.6	32.4
A	70	4.7	18.3	39.8
A	80	4.2	20.8	47.6
B	45	11.5	34.4	21.5
B	60	6.1	25.7	32.3
C	45	12.6	36.6	21.7
C	60	6.9	33.5	32.4

	ANB-3127 Avg.		TNT Avg.		TNT Equivalent	
r	p	i	p	i	Ep	Ei
40	14.1	42.5	22.0	47.5	64	89
50	9.6	32.5	12.3	37.0	78	88
60	6.8	26.0	8.3	30.0	82	87
70	4.9	21.0	5.8	26.0	84	81
80	3.5	18.5	4.1	23.5	85	79

Definition of Parameters with Units:

- r radial distance, feet
- p peak side-on overpressure, psig
- i side-on impulse, psi-msec
- t arrival time, msec
- Ep TNT equivalent based on overpressure, per cent
- Ei TNT equivalent based on impulse, per cent

Footnotes:

[a] Discarded points.

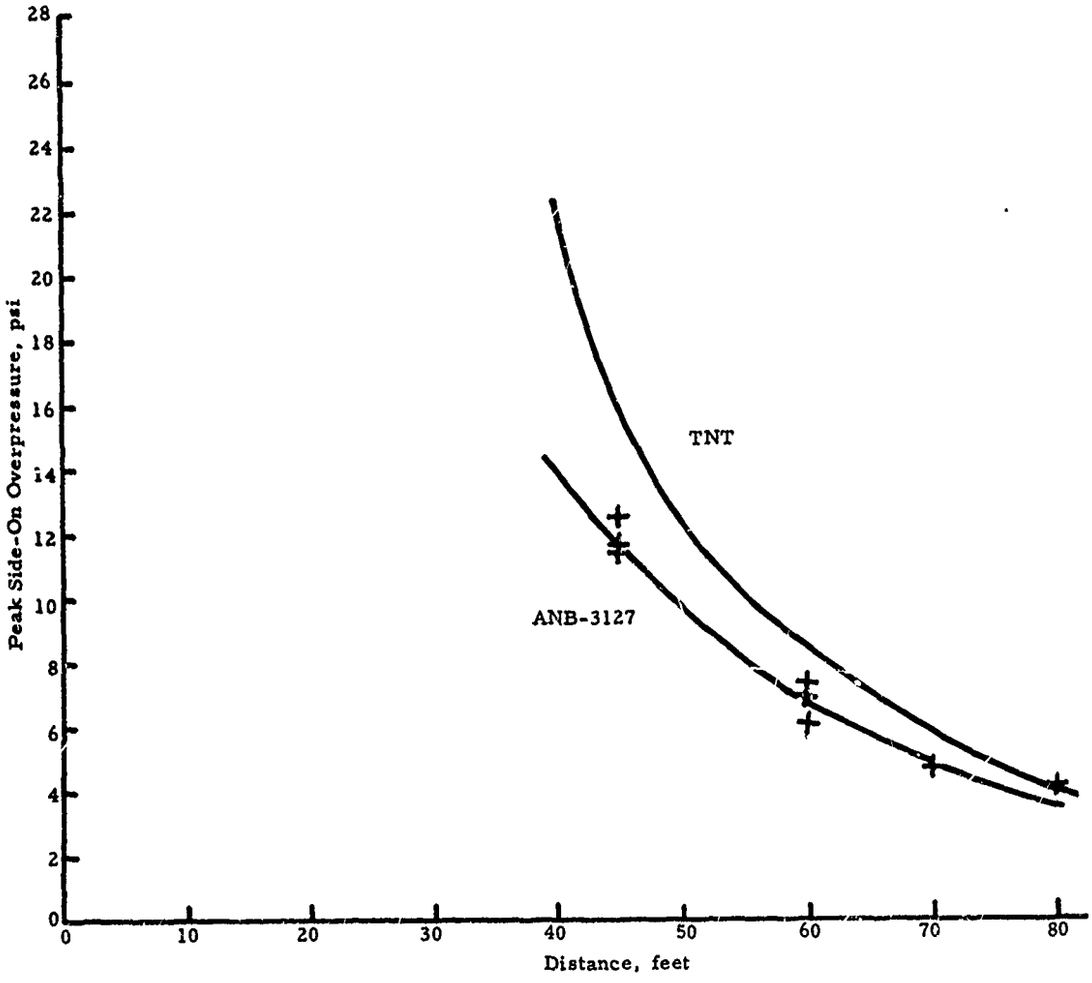

FIGURE 28. PEAK SIDE-ON OVERPRESSURE VS. DISTANCE FOR ANB-3127 PROPELLANT AND TNT

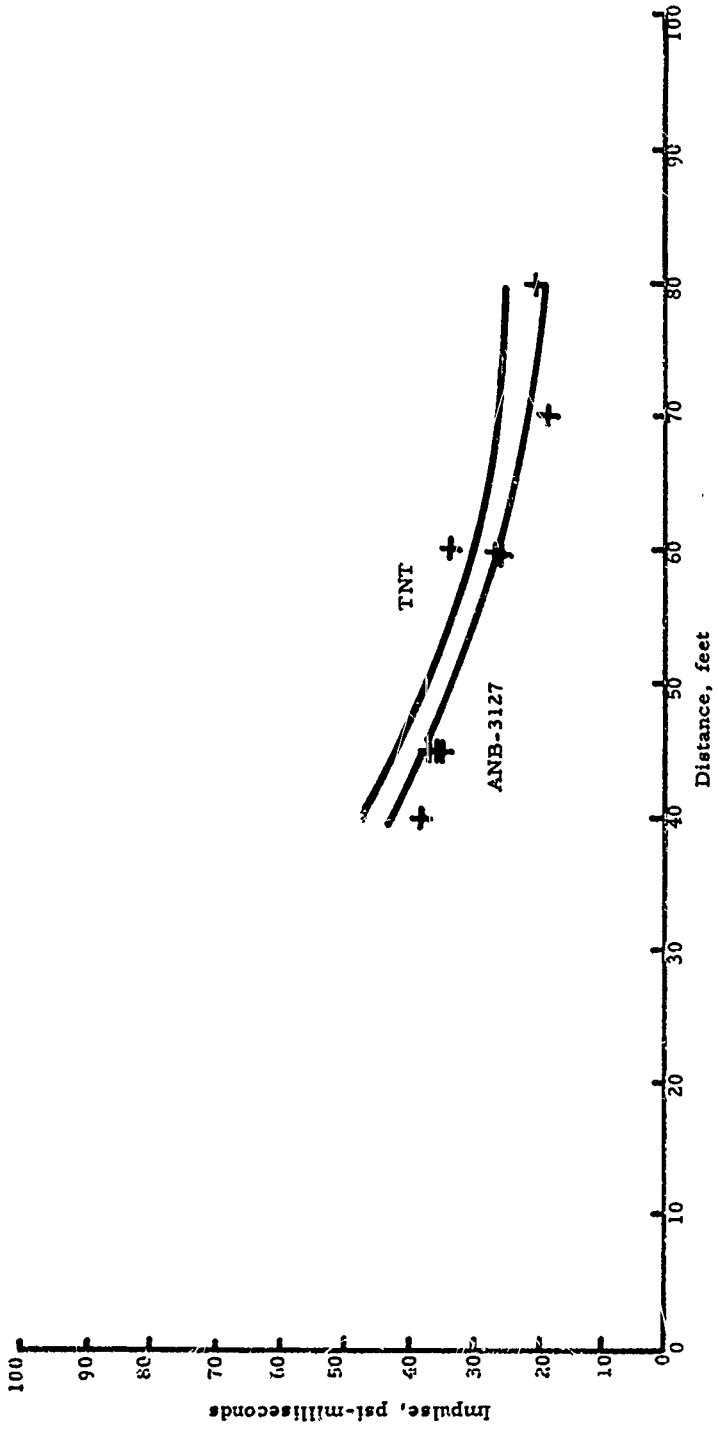

FIGURE 29. SIDE-ON IMPULSE VS. DISTANCE FOR ANB-3127 PROPELLANT AND TNT

Table XIII. Blast-Wave Data for ANP-2969 Propellant

Shot 122					Shot 141				
Leg	r	p	i	t	Leg	r	p	i	t
A	40	15.2	42.5	17.9	B	38	9.4	27.4	19.5
A	45	7.7	25.8	21.0	B	48	6.0	20.1	26.9
A	60	6.8	28.2	30.6	B	58	4.1	15.7	34.6
A	70	4.7	22.8	38.1	B	68	7.7[a]	41.9[a]	50.9[a]
A	80	3.3	20.8	45.8	B	78	1.9	6.5	29.5
B	45	8.0	26.2	20.9	A	50	6.7	20.1	29.0
C	45	8.7	21.4	20.7	A	80	1.8	6.2	54.9
C	60	7.5	28.4	31.1	C	50	7.5	34.0	45.4

	ANP-2969 Avg.		TNT Avg.		TNT Equivalent	
r	p	i	p	i	Ep	Ei
40	10.3	35.0	22.0	47.5	47	74
50	7.3	28.5	12.3	37.0	59	77
60	5.2	22.0	8.3	30.0	63	73
70	3.6	17.0	5.8	26.0	62	65
80	2.5	13.5	4.1	23.5	61	57

Definition of Parameters with Units:

r	radial distance, feet
p	peak side-on overpressure, psig
i	side-on impulse, psi-msec
t	arrival time, msec
Ep	TNT equivalent based on overpressure, per cent
Ei	TNT equivalent based on impulse, per cent

Footnotes:

[a] Discarded points.

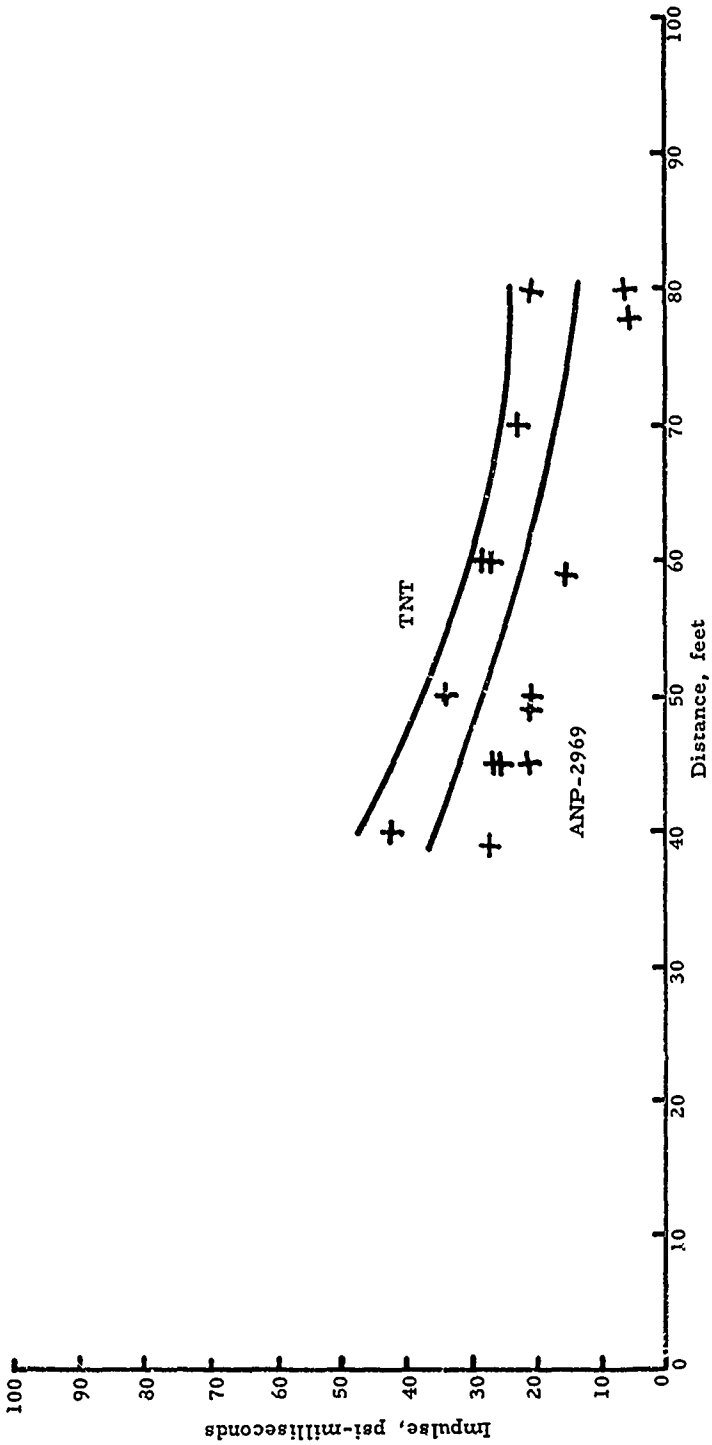

FIGURE 30. PEAK SIDE-ON OVERPRESSURE VS. DISTANCE FOR ANP-2969 PROPELLANT AND TNT

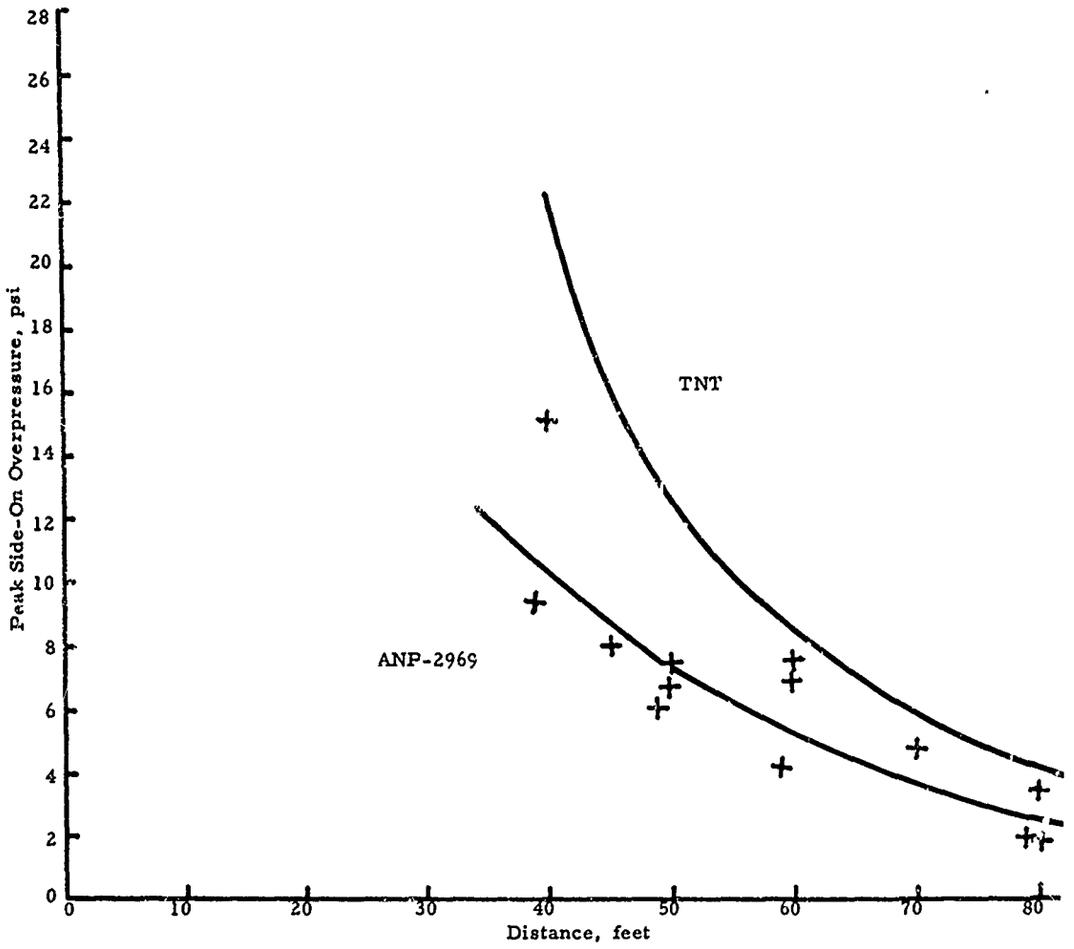

FIGURE 31. SIDE-ON IMPULSE VS. DISTANCE FOR ANP-2969 PROPELLANT AND TNT

Table XIV Blast-Wave Data for ANP-3066 Propellant

Shot 125					Shot 139				
Leg	r	p	i	t	Leg	r	p	i	t
A	40	16.3	44.0	18.4	B	47	10.9	30.3	22.2
A	45	10.5	34.8	21.6	B	57	6.9	23.0	29.8
A	60	6.4	25.3	32.3	B	67	5.7	24.7	37.4
A	70	4.3	30.6	39.9	B	77	3.9	19.6	45.3
B	45	12.0	40.3	21.6	A	50	9.0	35.0	27.1
B	60	6.5	26.3	32.3	C	50	8.9	28.3	27.3
C	45	12.3	39.0	21.7	C	70	4.9	24.2	42.5
C	60	6.7	26.8	32.4					

	ANP-3066 Avg.		TNT Avg.		TNT Equivalent	
r	p	i	p	i	Ep	Ei
40	14.4	43.5	22.0	47.5	65	92
50	9.7	33.0	12.3	37.0	79	89
60	6.9	26.0	8.3	30.0	82	86
70	4.8	21.5	5.8	26.0	83	82
80	3.3	18.0	4.1	23.5	81	76

Definition of Parameters with Units:

- r radial distance, feet
- p peak side-on overpressure, psig
- i side-on impulse, psi-msec
- t arrival time, msec
- Ep TNT equivalent based on overpressure, per cent
- Ei TNT equivalent based on impulse, per cent

Footnotes:

[a] Discarded points.

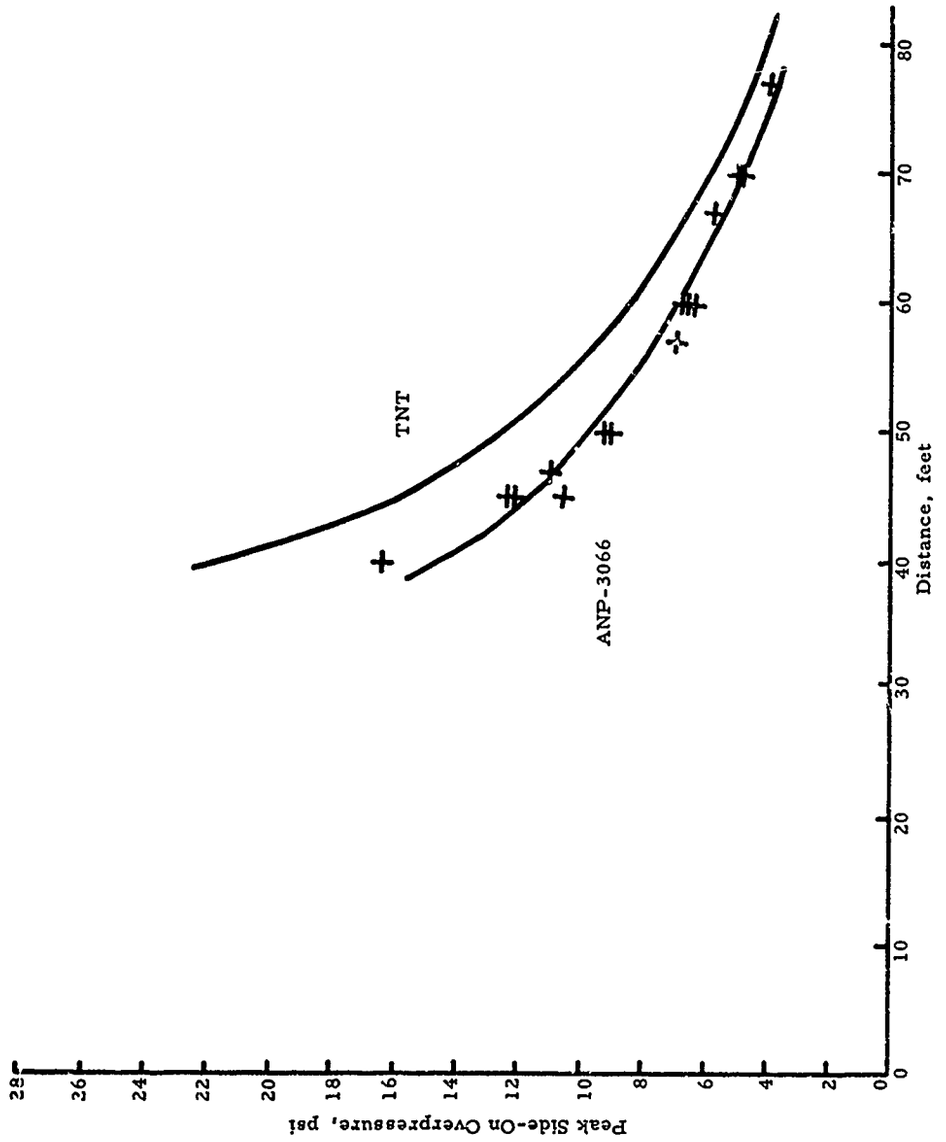

FIGURE 32. PEAK SIDE-ON OVERPRESSURE VS. DISTANCE FOR ANP-3066 PROPELLANT AND TNT

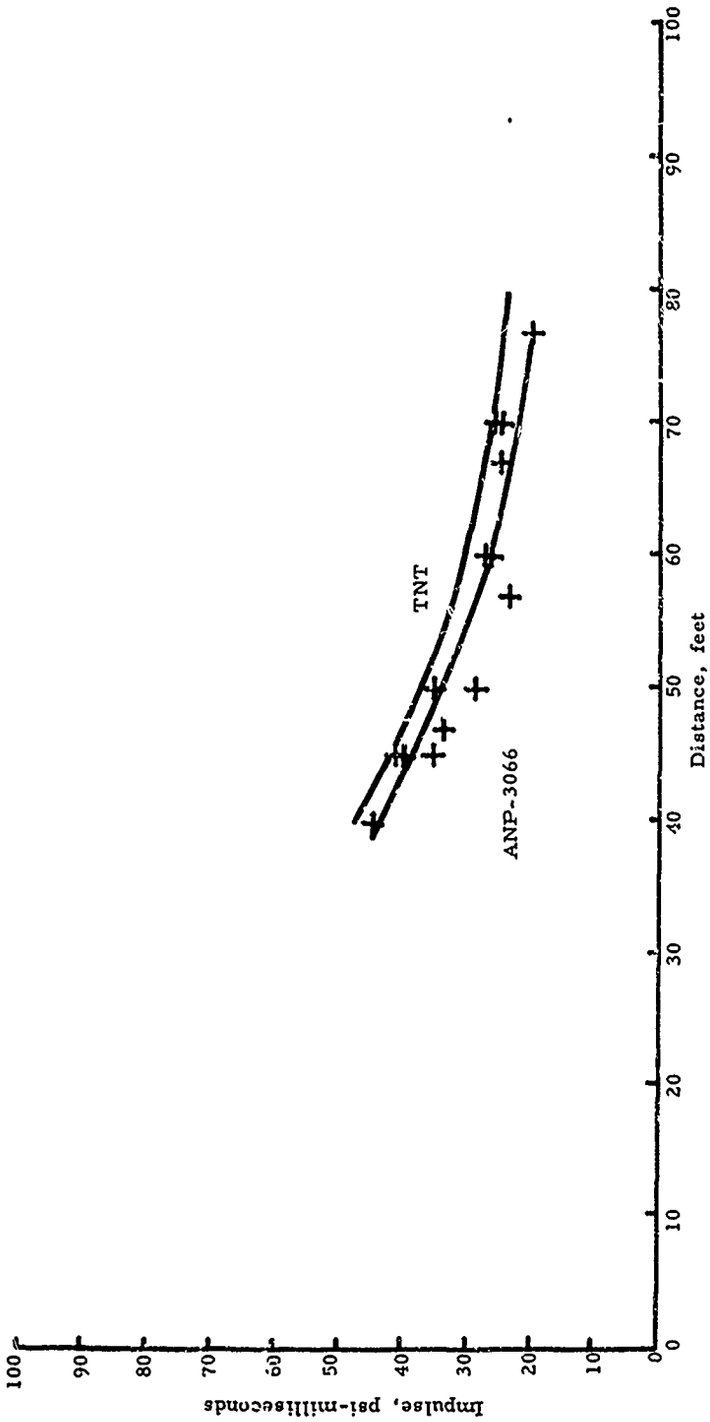

FIGURE 33. SIDE-ON IMPULSE VS. DISTANCE FOR ANP-3066 PROPELLANT AND TNT

Table XV Blast-Wave Data for ANP-3146 Propellant

Shot 110					Shot 138				
Leg	r	p	i	t	Leg	r	p	i	t
A	40	14.9	39.0	18.0	B	37	8.0	38.9	27.7
A	45	11.3	41.3	21.4	B	57	12.3	46.3	16.3
A	60	6.3	28.4	32.3	B	67	10.6	34.4	22.9
A	70	4.5	24.4	41.0	B	77	6.9	28.5	30.1
A	80	3.3	18.8	48.9	In Order of t				
B	45	8.5	40.5	21.5	B	37	12.3	46.3	16.3
B	60	5.9	26.6	32.4	B	47	10.6	34.4	22.9
C	45	12.2	33.0	21.5	B	57	8.0	38.9	27.7
C	60	6.4	26.2	32.3	B	67	6.9	28.5	30.1

	ANP-3146 Avg.		TNT Avg.		TNT Equivalent	
r	p	i	p	i	Ep	Ei
40	14.9	39.5	22.0	47.5	68	81
50	9.3	32.0	12.3	37.0	76	86
60	6.5	27.5	8.3	30.0	78	92
70	4.6	23.0	5.8	26.0	79	89
80	3.3	20.0	4.1	23.5	80	85

Definition of Parameters with Units:

r	radial distance, feet
p	peak side-on overpressure, psig
i	side-on impulse, psi-msec
t	arrival time, msec
Ep	TNT equivalent based on overpressure, per cent
Ei	TNT equivalent based on impulse, per cent

Footnotes:

[a] Discarded points.

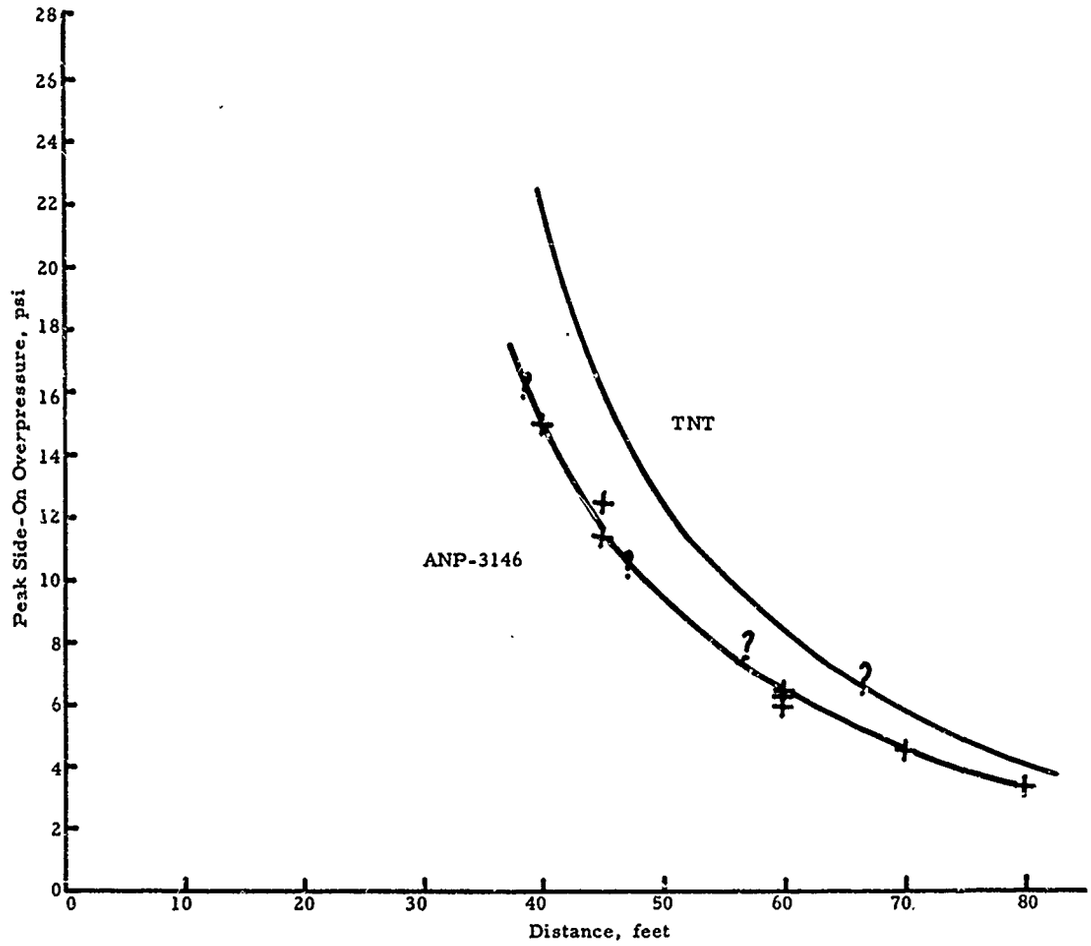

FIGURE 34. PEAK SIDE-ON OVERPRESSURE VS. DISTANCE FOR ANP-3146 PROPELLANT AND TNT

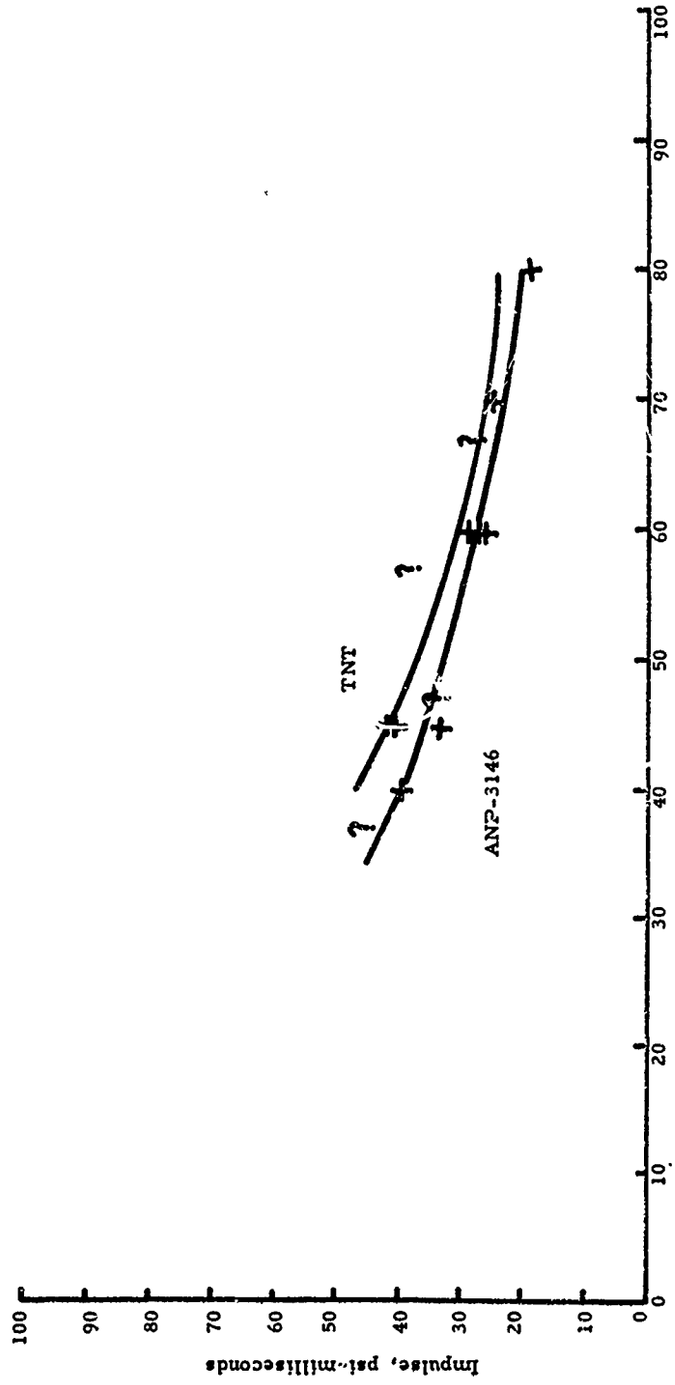

FIGURE 35. SIDE-ON IMPULSE VS. DISTANCE FOR ANP-3146 PROPELLANT AND TNT

Table XVI Blast-Wave Data for ANP-3196 Propellant

Shot 109					Shot 141				
Leg	r	p	i	t	Leg	r	p	i	t
A	40	10.3	24.7	21.0	B	38	9.4	27.3	19.5
A	45	7.6	22.9	24.6	B	58	4.1	15.7	34.6
A	60	4.2	17.2	36.1	B	68	7.7[a]	41.9[a]	51.0
A	70	2.6	14.7	44.2	B	78	1.9	6.5[a]	29.5
A	80	2.9	11.9	52.4	A	50	6.7	20.1	29.1
B	45	8.1	23.6	24.2	A	80	1.8	6.3[a]	54.9
B	60	4.5	18.6	35.5	C	50	7.5	33.9[a]	45.3
C	45	10.3	23.2	24.0					
C	60	4.7	16.1	35.4					

	ANP-3196 Avg.		TNT Avg.		TNT Equivalent	
r	p	i	p	i	Ep	Ei
40	10.2	26.5	22.0	47.5	46	56
50	7.0	21.5	12.3	37.0	57	58
60	4.6	17.5	8.3	30.0	55	58
70	3.2	14.5	5.8	26.0	55	56
80	2.2	12.0	4.1	23.5	54	51

Definition of Parameters with Units:

- r radial distance, feet
- p peak side-on overpressure, psig
- i side-on impulse, psi-msec
- t arrival time, msec
- Ep TNT equivalent based on overpressure, per cent
- Ei TNT equivalent based on impulse, per cent

Footnotes:

[a] Discarded points.

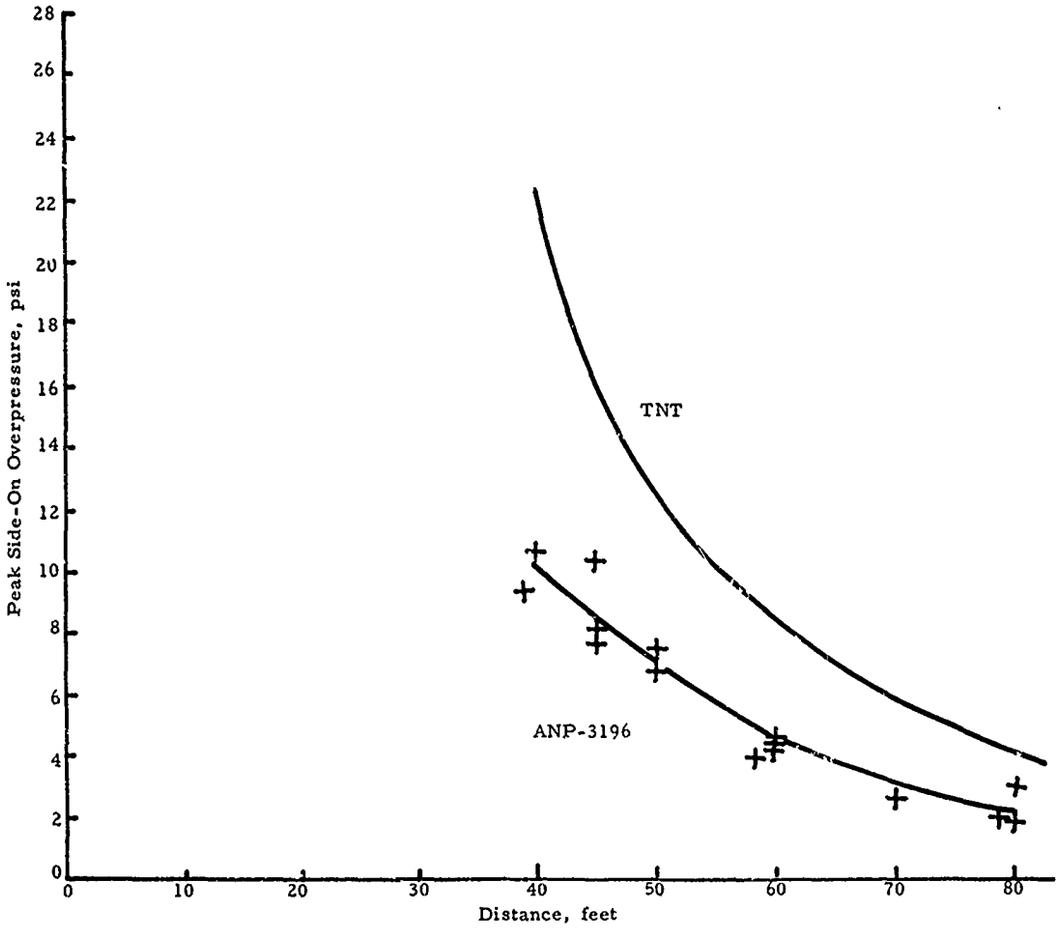

FIGURE 36. PEAK SIDE-ON OVERPRESSURE VS. DISTANCE FOR ANP-3196 PROPELLANT AND TNT

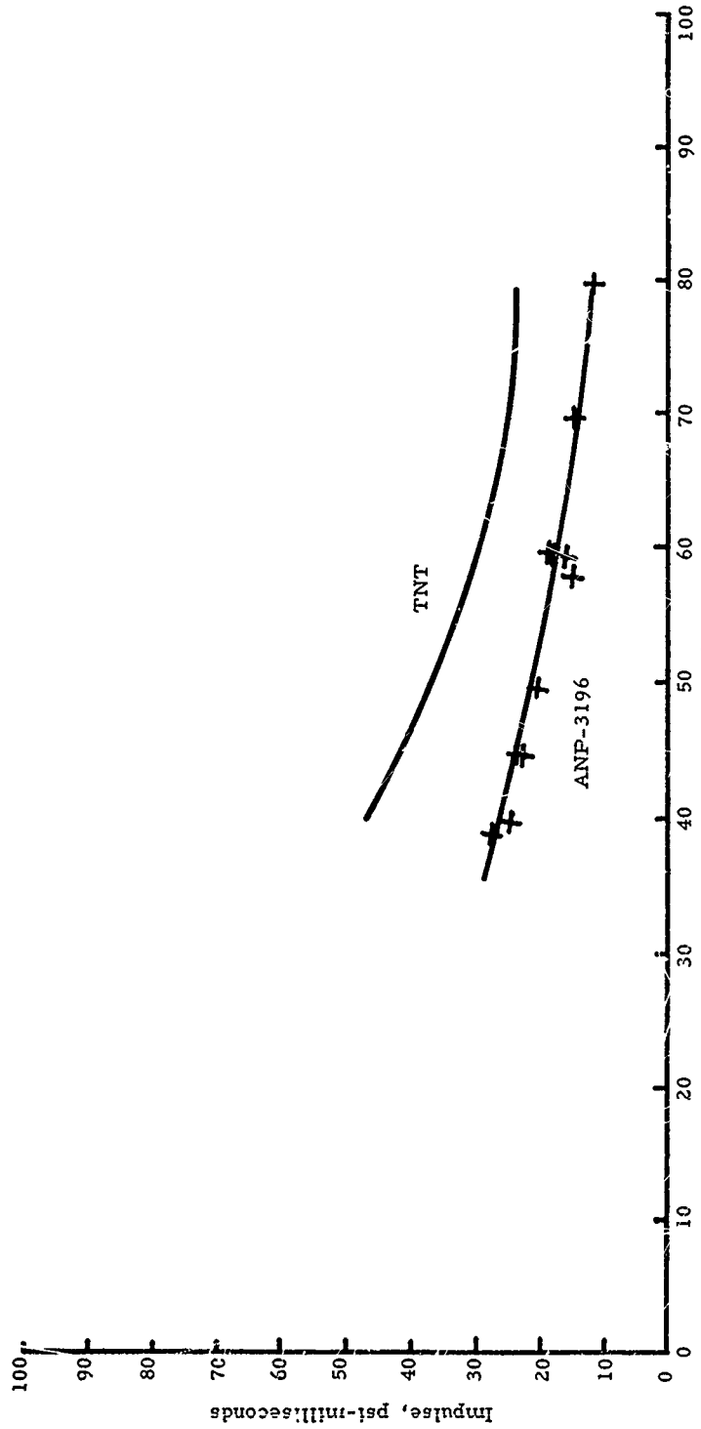

FIGURE 37. SIDE-ON IMPULSE VS. DISTANCE FOR ANP-3196 PROPELLANT AND TNT

Table XVII Blast-Wave Data for C-129 Propellant

Shot 123					Shot 142				
Leg	r	p	i	t	Leg	r	p	i	t
A	40	10.2	31.7	19.6	B	38	11.8	40.5	18.3
A	45	9.3	25.4	23.2	B	48	9.7	34.4	25.4
A	60	5.0	21.7	34.4	B	58	5.9	32.9	21.3
A	70	3.7	19.9	42.3	B	68	5.2	21.4	40.6
A	80	2.8	14.4	50.3	B	78	3.3	18.4	48.6
B	45	8.4	29.9	23.0	A	50	8.5	28.4	26.9
B	60	5.7	22.1	34.2	C	50	7.9	25.6	27.4
C	60	5.0	19.6	34.5	C	80	4.3	19.7	43.0

	C-129 Avg.		TNT Avg.		TNT Equivalent	
r	p	i	p	i	Ep	Ei
40	11.0	36.0	22.0	47.5	50	76
50	8.2	28.5	12.3	37.0	66	77
60	6.2	23.5	8.3	30.0	75	77
70	4.6	20.0	5.8	26.0	79	78
80	3.3	18.5	4.1	23.5	81	79

Definition of Parameters with Units:

r	radial distance, feet
p	peak side-on overpressure, psig
i	side-on impulse, psi-msec
t	arrival time, msec
Ep	TNT equivalent based on overpressure, per cent
Ei	TNT equivalent based on impulse, per cent

Footnotes:

[a] Discarded points.

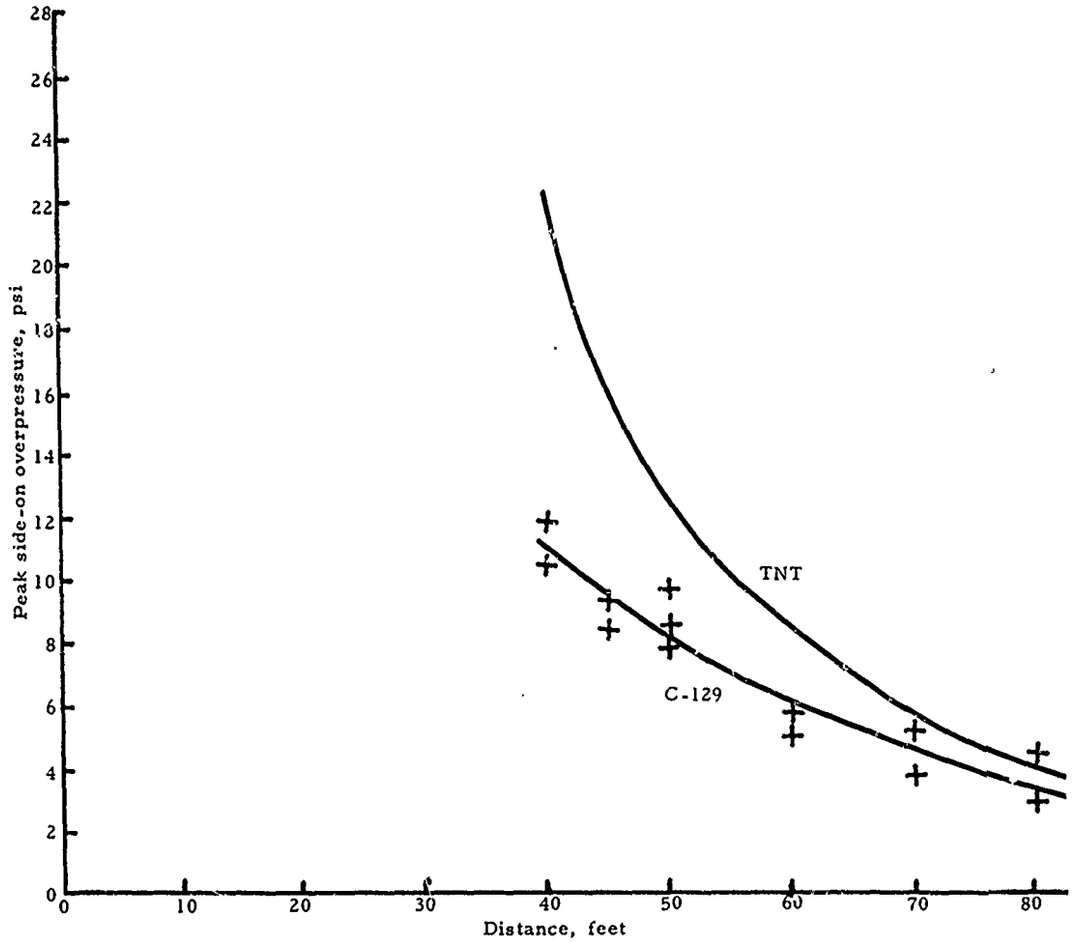

FIGURE 38. PEAK SIDE-ON OVERPRESSURE VS. DISTANCE FOR C-129 PROPELLANT AND TNT

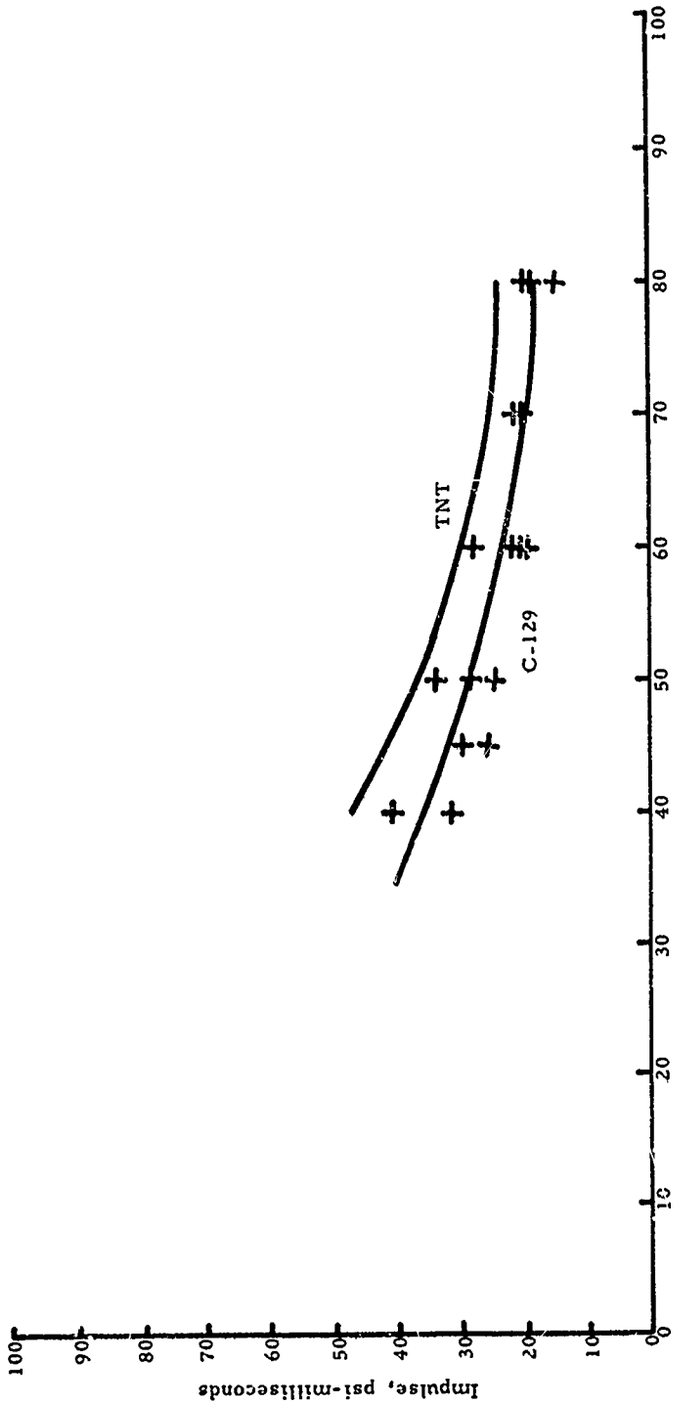

FIGURE 39. SIDE-ON IMPULSE VS. DISTANCE FOR C-129 PROPELLANT AND TNT

Table XVIII. Blast-Wave Data for TP-H-7020 Propellant

Shot 124

Leg	r	p	i	t
A	40	12.8	38.5	17.9
A	45	10.3	27.5	21.3
A	60	5.9	25.0	32.0
A	70	3.7	24.9	39.7
A	80	4.3	20.9	47.6
B	45	7.4[a]	36.3	21.1
B	60	5.2	27.7	31.9
C	60	6.9	27.3	32.2

	TP-H-7020 Avg.		TNT Avg.		TNT Equivalent	
r	p	i	p	i	Ep	Ei
40	12.6	36.0	22.0	47.5	57	76
50	8.4	30.5	12.3	37.0	68	83
60	5.8	26.0	8.3	30.0	70	87
70	4.2	23.5	5.8	26.0	72	90
80	3.1	21.0	4.1	23.5	75	90

Definition of Parameters with Units:

- r radial distance, feet
- p peak side-on overpressure, psig
- i side-on impulse, psi-msec
- t arrival time, msec
- Ep TNT equivalent based on overpressure, per cent
- Ei TNT equivalent based on impulse, per cent

Footnotes:

[a] Discarded points.

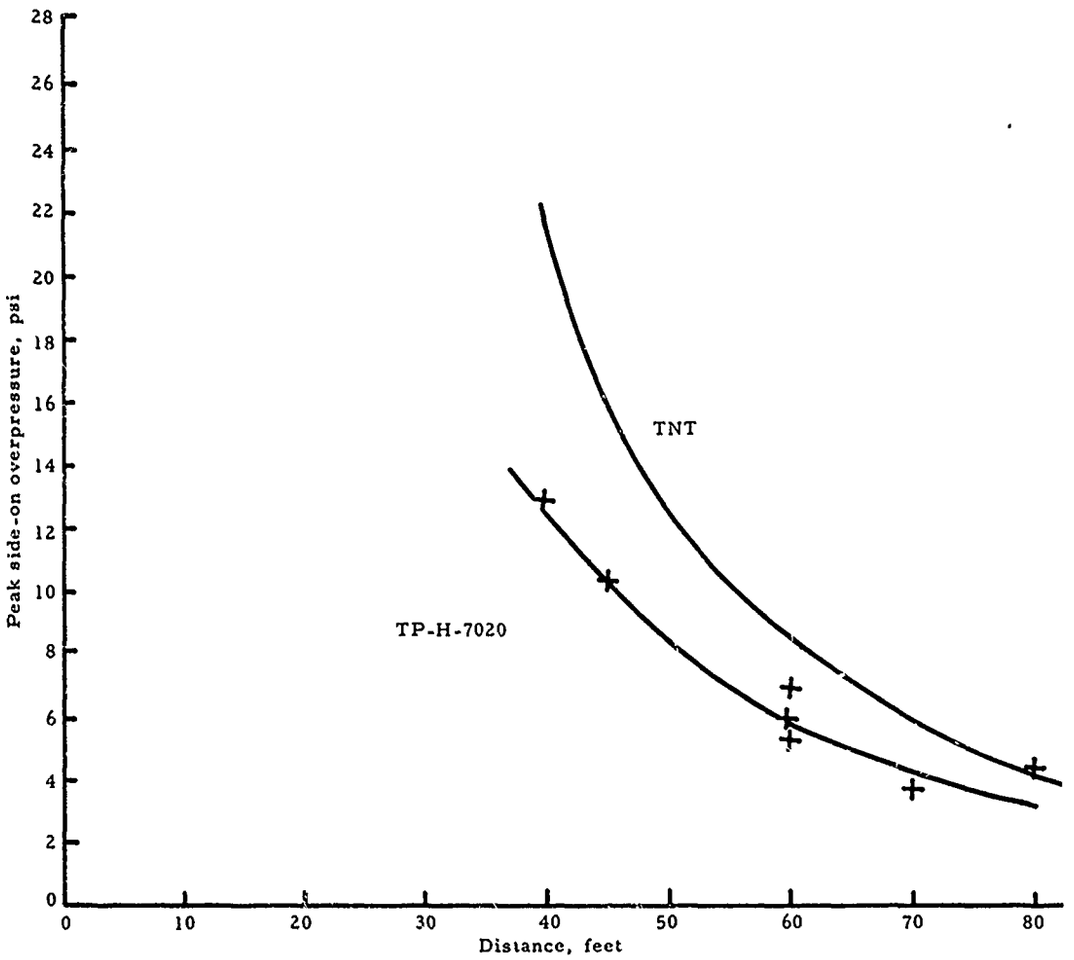

FIGURE 40. PEAK SIDE-ON OVERPRESSURE VS. DISTANCE FOR TP-H-7020 PROPELLANT AND TNT

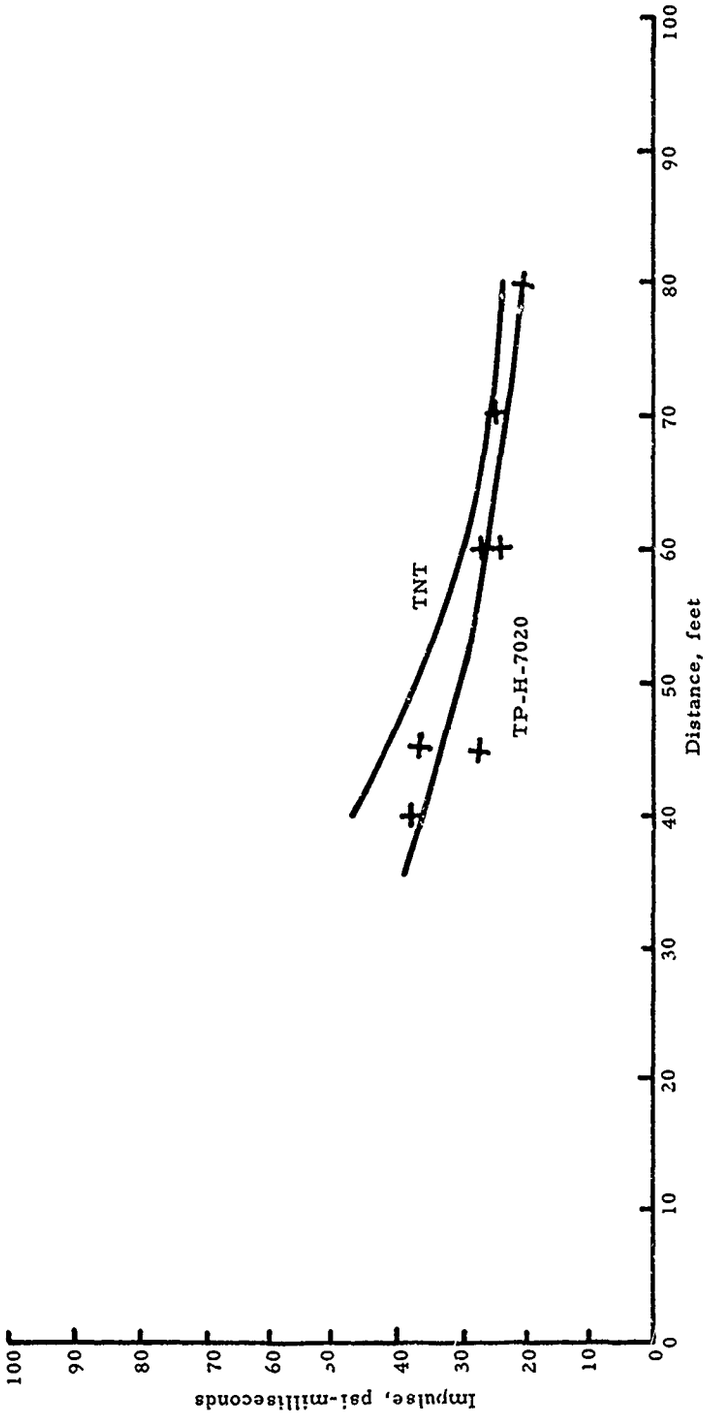

FIGURE 41. SIDE-ON IMPULSE VS. DISTANCE FOR TP-H-7020 PROPELLANT AND TNT

Table XIX Blast-Wave Data for TP-H-7022 Propellant

Shot 108

Leg	r	p	i	t
A	40	15.7	35.2	18.5
A	45	13.2	28.8	21.9
A	60	5.1	24.4	32.9
A	80	3.6	18.8	48.8
B	45	12.1	42.4[a]	21.4
B	60	4.6	24.6	32.3
C	45	12.6	31.7	21.4

	TP-H-7002 Avg.		TNT Avg.		TNT Equivalent	
r	p	i	p	i	Ep	Ei
40	16.3	34.5	22.0	47.5	74	73
50	9.5	28.5	12.3	37.0	77	74
60	6.2	23.4	8.3	30.0	75	75
70	4.5	20.5	5.8	26.0	78	79
80	3.3	18.5	4.1	23.5	80	82

Definition of Parameters with Units:

- r radial distance, feet
- p peak side-on overpressure, psig
- i side-on impulse, psi-msec
- t arrival time, msec
- Ep TNT equivalent based on overpressure, per cent
- Ei TNT equivalent based on impulse, per cent

Footnotes:

[a] Discarded points.

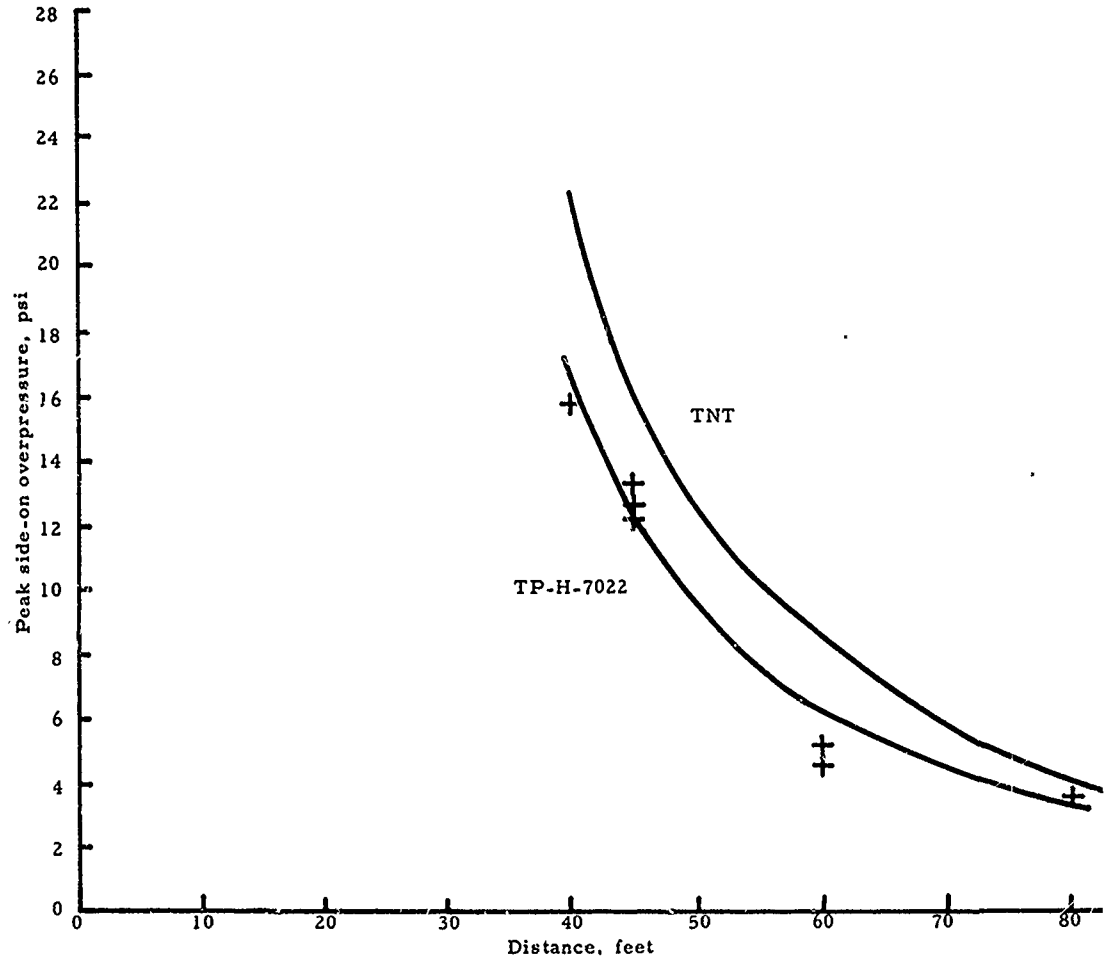

FIGURE 42. PEAK SIDE-ON OVERPRESSURE VS. DISTANCE FOR TP-H-7022 PROPELLANT AND TNT

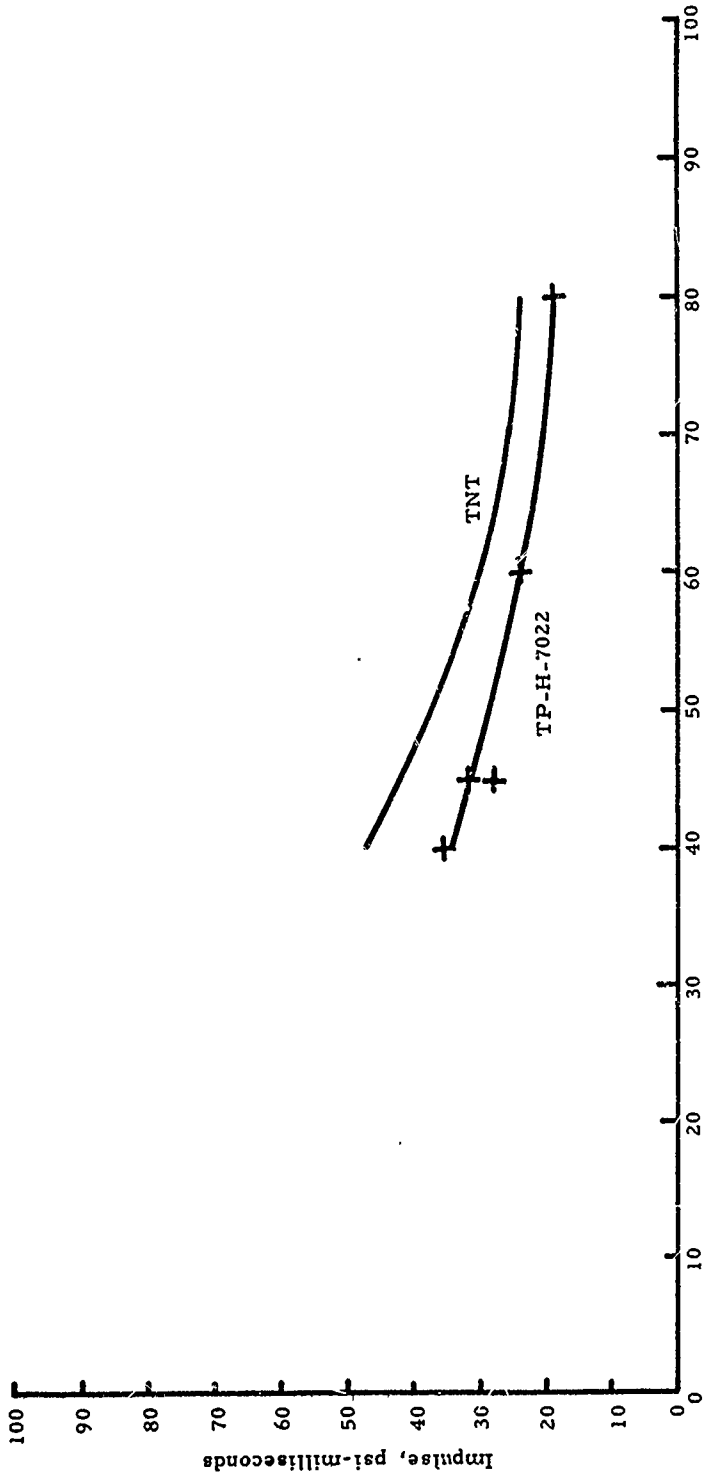

FIGURE 43. SIDE-ON IMPULSE VS. DISTANCE FOR TP-H-7022 PROPELLANT AND TNT

Table XX. Blast-Wave Data for TP-H-7028 Propellant

Shot 126

Leg	r	p	i	t
A	40	4.5[a]	40.0	18.4
A	45	9.3	30.6	21.8
A	60	7.3	24.9	32.7
A	70	4.2	19.2	40.5
A	80	3.7	17.2	48.3
B	45	9.7	36.2	22.1
B	60	5.0	26.9	33.3
C	45	11.0	35.0	21.4
C	60	5.9	25.4	33.0

	TP-H-7028 Avg.		TNT Avg.		TNT Equivalent	
r	p	i	p	i	Ep	Ei
40	11.7	38.0	22.0	47.5	53	80
50	8.8	31.5	12.3	37.0	71	85
60	6.5	26.0	8.3	30.0	78	87
70	4.6	21.0	5.8	26.0	80	81
80	3.2	17.0	4.1	23.5	78	72

Definition of Parameters with Units:

- r radial distance, feet
- p peak side-on overpressure, psig
- i side-on impulse, psi-msec
- t arrival time, msec
- Ep TNT equivalent based on overpressure, per cent
- Ei TNT equivalent based on impulse, per cent

Footnotes:

[a] Discarded points.

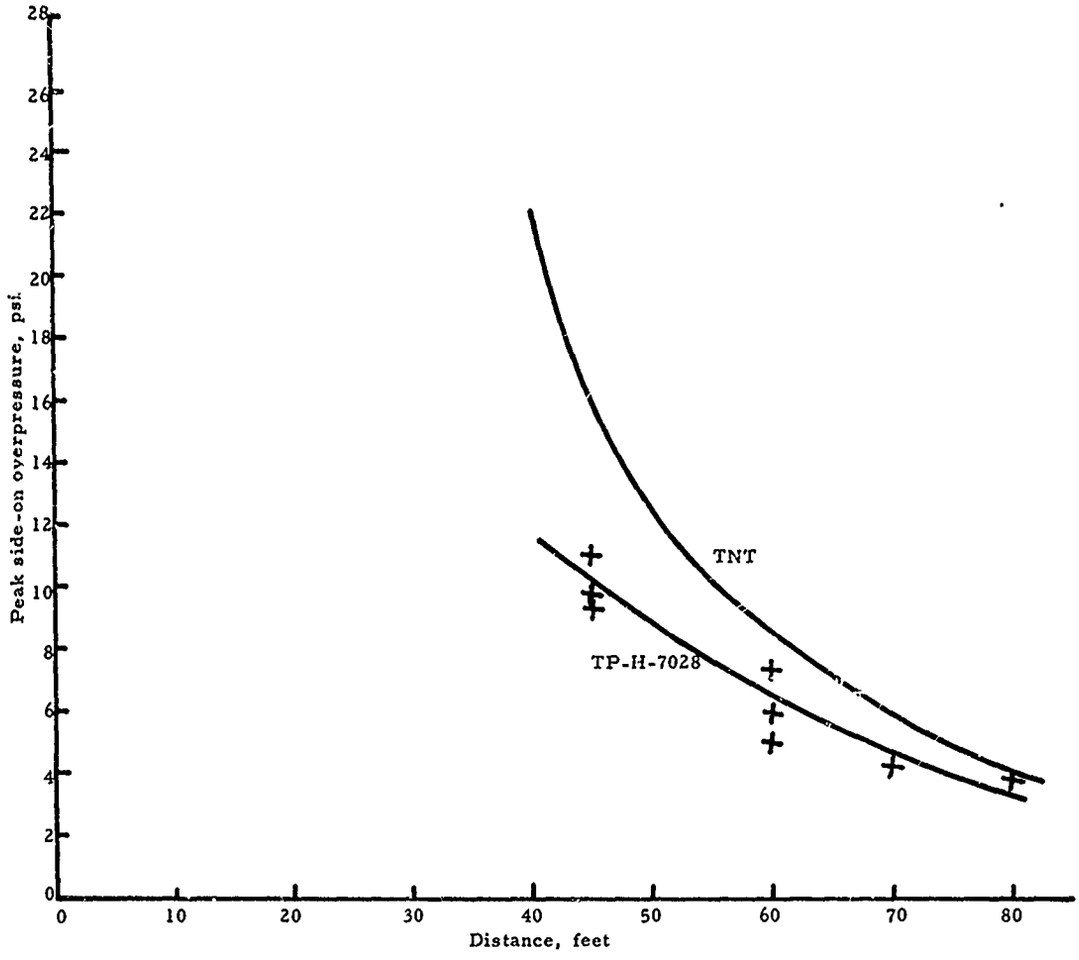

FIGURE 44. PEAK SIDE-ON OVERPRESSURE VS. DISTANCE FOR TP-H-7028 PROPELLANT AND TNT

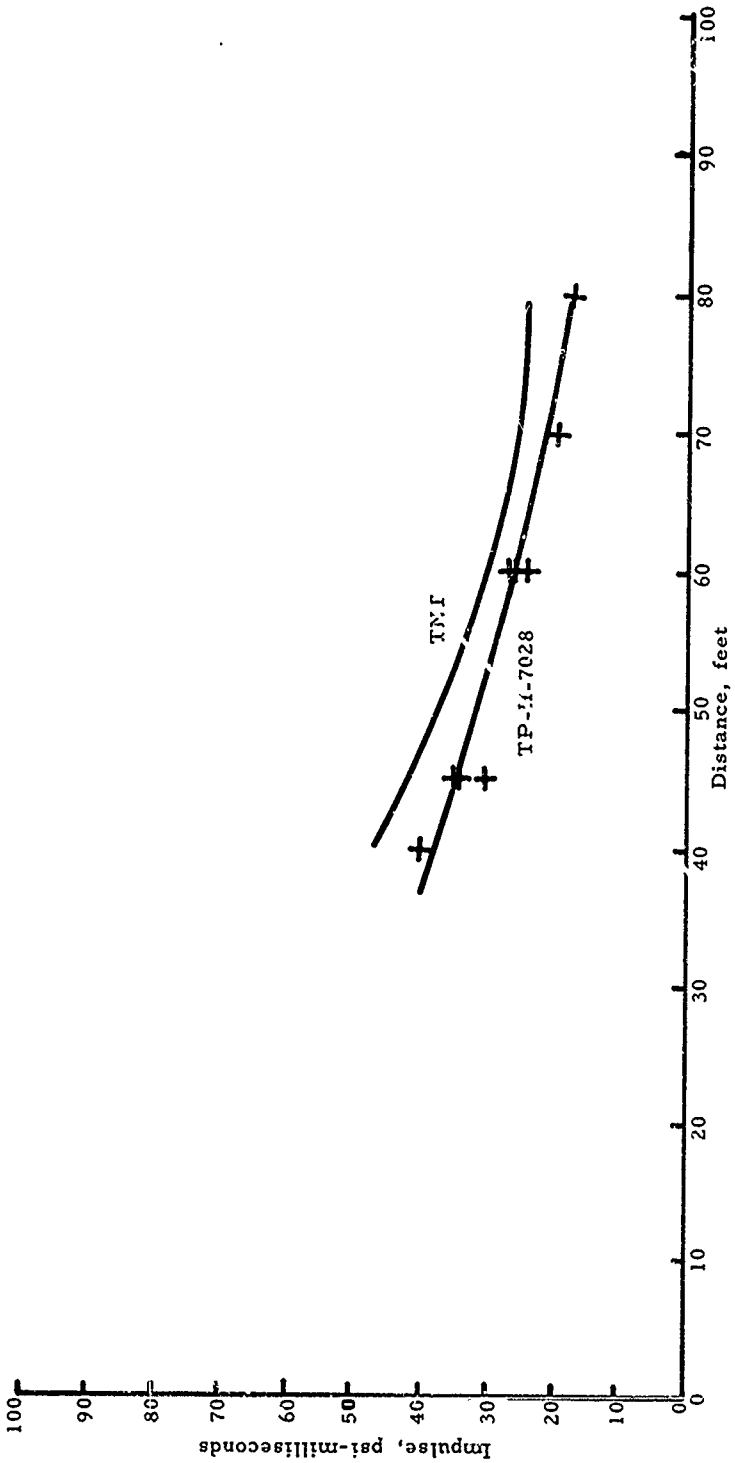

FIGURE 45. SIDE-ON IMPULSE VS. DISTANCE FOR TP-H-7028 PROPELLANT AND TNT

Table XXI Blast-Wave Data for RH-P-112 Propellant

Shot 136					Shot 137				
Leg	r	p	i	t	Leg	r	p	i	t
B	40	20.5	52.1	14.6	B	40	15.7	49.6	16.9
B	50	11.7	38.7	21.1	B	50	4.6[a]	34.6[a]	23.5
B	60	7.4	34.1	28.2	B	60	5.1	27.0	30.9
B	70	6.0	30.3	35.7	B	70	4.5	25.9	38.3
B	80	4.3	26.7	43.6	B	80	3.8	---	---
A	50	13.6	47.0	21.0	A	50	9.7	44.4	23.4
A	80	4.7	19.0	43.3	A	80	3.4	25.9	46.4
C	50	12.7	40.1	21.0	C	50	10.2	35.0	23.7
C	70	6.2	27.3	35.5	C	70	5.3	22.7	38.4

	RH-P-112 Avg.		TNT Avg.		TNT Equivalent	
r	p	i	p	i	Ep	Ei
40	---	---	22.0	47.5	--	--
50	---	---	12.3	37.0	--	--
60	---	---	8.3	30.0	~100	~100
70	---	---	5.8	26.0	--	--
80	---	---	4.1	23.5	--	--

Definition of Parameters with Units:

r	radial distance, feet
p	peak side-on overpressure, psig
i	side-on impulse, psi-msec
t	arrival time, msec
Ep	TNT equivalent based on overpressure, per cent
Ei	TNT equivalent based on impulse, per cent

Footnotes:

[a] Discarded points.

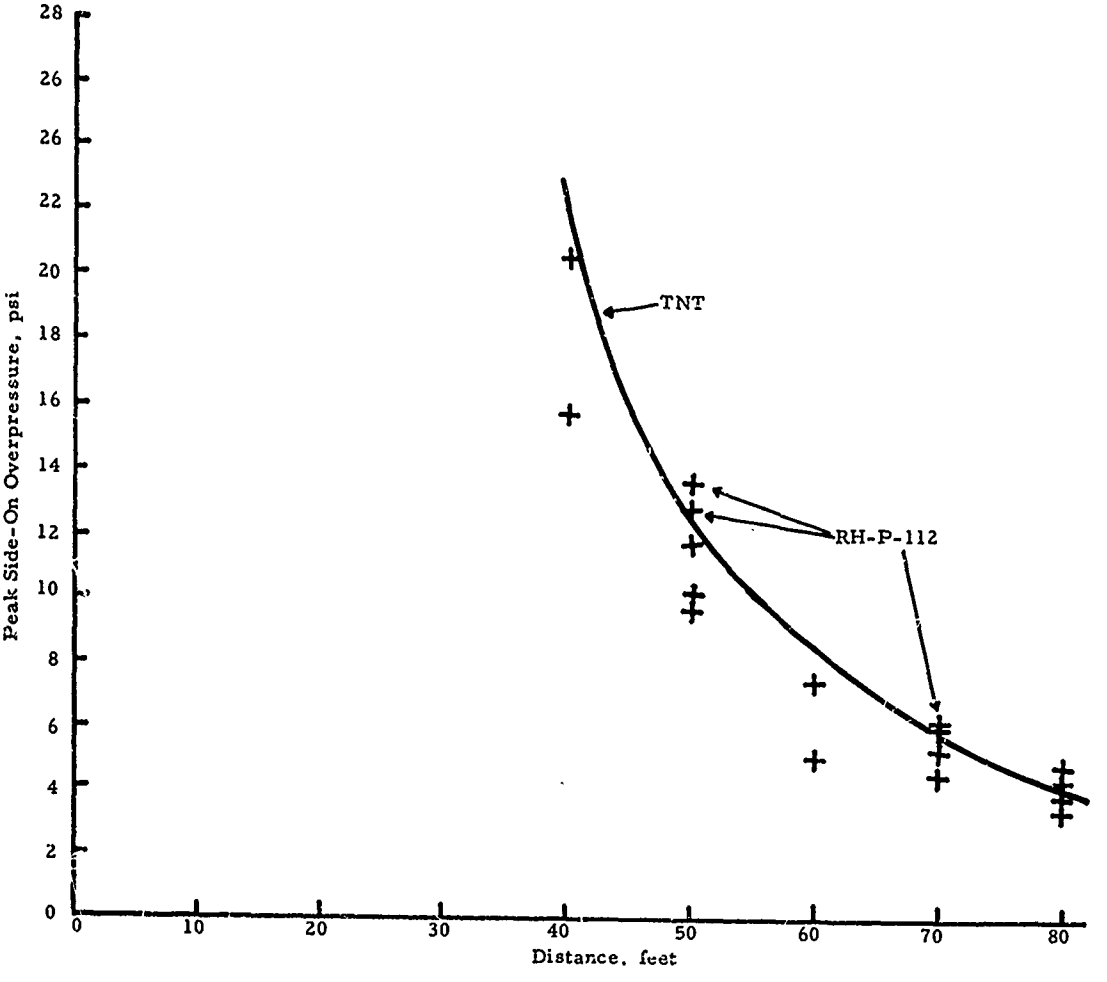

FIGURE 46. PEAK SIDE-ON OVERPRESSURE VS. DISTANCE FOR RH-P-112 PROPELLANT AND TNT

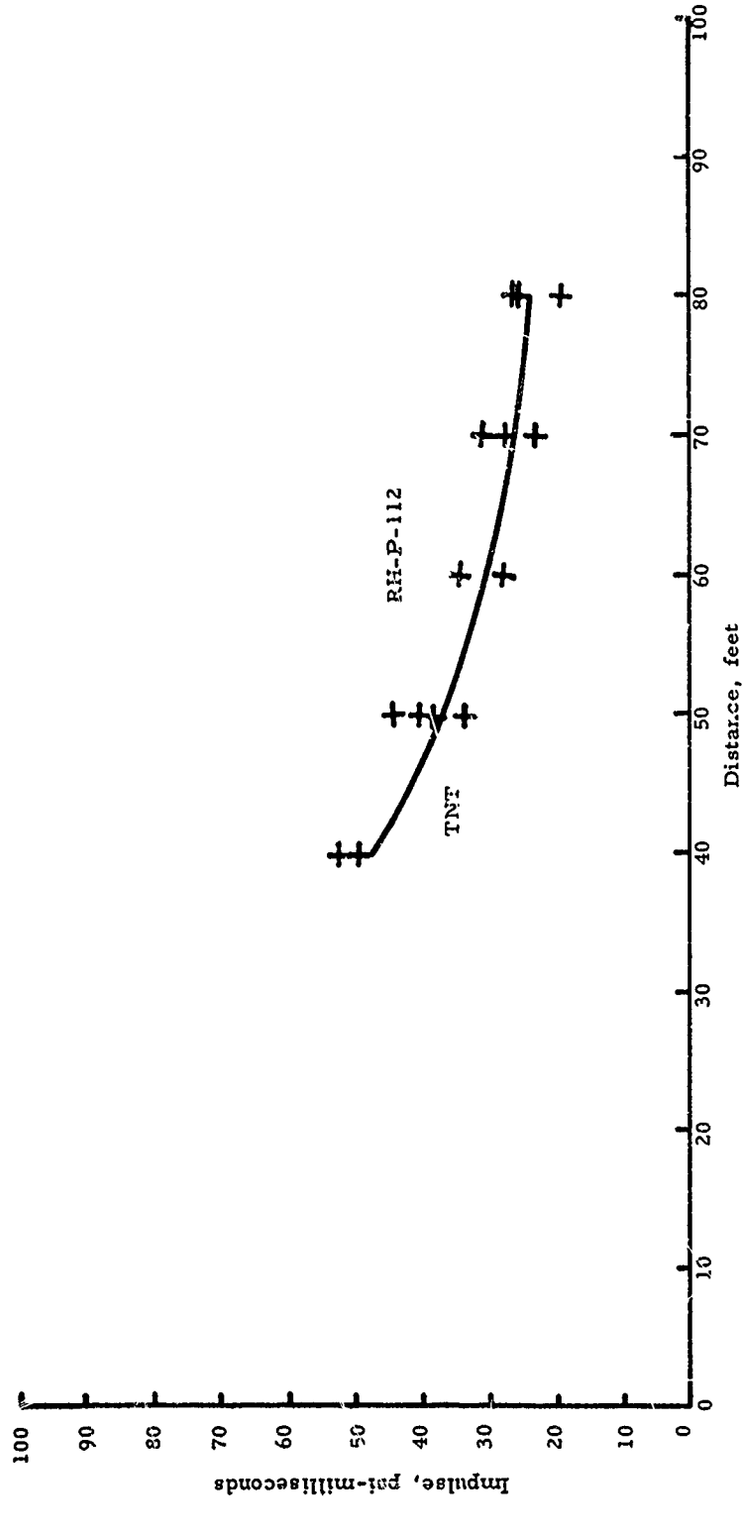

FIGURE 47. SIDE-ON IMPULSE VS. DISTANCE FOR RH-P-112 PROPELLANT AND TNT

REFERENCES

1. E. G. Johnson, PROPELLANT HAZARDS RESEARCH FACILITY, in preparation.

2. G. F. Kinney, EXPLOSIVE SHOCKS IN AIR, New York, The Macmillan Company, 1962.

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13. ABSTRACT

Peak side-on overpressure and side-on impulse as a function of distance have been determined for 17 propellant formulations in a series of 31 shots. TNT equivalents based on overpressure and TNT equivalents based on impulse have been assigned the formulations examined. Blast overpressures and impulses were generated by 100-lbm propellant charges initiated with 25 lbm of high explosive and measured at distances from 40 to 80 feet from ground zero. It has been found that, depending on formulation, non-detonable propellants exhibit a TNT equivalent of 55 to 85 and that detonable propellants exhibit a TNT equivalent of 100 to 140. These TNT equivalents should be used in hazards classification only when stimuli are comparable.

DD FORM 1 NOV 65 1473 REPLACES DD FORM 1473, 1 JAN 64, WHICH IS OBSOLETE FOR ARMY USE.

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Blast wave Overpressure Impulse Solid propellants TNT equivalents						